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INDEX, VOL. XVIII.

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PAGE

Air Compressors, Notes on, by Robert Peele 196, 309
Alumni and University News 81, 185, 303
Analytical Chemistry, Abstracts in, by Elwyn Waller..... 39, 169, 430
Absolute Method for Nitrogen..... 56
Acidimetric Standardization..... 430
Alkalimetric Carbonates in Lyes and Alkaline Carbonates..... 431
Alkalimetric Indicators 170
Alkalimetric Solutions..... 430
Alloys of Lead, Tin, Antimony and Copper..... 46
Alumina and Ferric Oxide in Phosphates 432
Aluminum 41
Aluminum Alloys..... 41
Aluminum Analysis 40
Ammonia free water for Nesslerizing 39
Ammonium Citrate in Fertilizer Analyses 39
Ammonium Sulphide Group; Qualitative Tests 40
Analysis of Iodides..... 439
Analysis of Mortar 57
Analysis of Nitroglycerine..... 443
Analysis of Percussion Cap Composition 176
Analysis of Refined Zinc..... 171
Antimony in Ores, etc..... 47
Argon Determination, Absorbent for Nitrogen in..... 56
Arsenic by Reinsch's test..... 171
Arsenic in Alloys of Tin and Lead..... 47
Arsenic in Crude Oil of Vitriol..... 47
Arsenic in Presence of Selenium..... 47
Arsenic, Volumetric Method..... 438
Bacic Acetate precipitations (Ferric)..... 432
Bismuth Sulphide 45, 172
Boiler Scale 57
Boric Acid..... 440, 441
Boric Acid in Food..... 441
Cadmium..... 49
Cadmium Estimation..... 172
Calcium Carbide as a Reducing Agent in the Laboratory..... 170

Calcium Oxalate precipitation 170
Calcium Sulphate and Carbonate in White Paint 432
Carbon 41, 171
Carbon Dioxide 55
Carbon Dioxide in Air 55, 174
Carbon in Ferrochrome 442
Carbonic Acid by Iodometric Method 443
Caustic Alkali in Presence of Carbonates 431
Cement Mortars 58
Chromium Alloy 42
Chromium Hydroxide in precipitation 42
Chromium in Steel 42
Chrome Ore and Ferrochrome 43
Cobalt in Presence of Nickel 44
Colorimetric for Copper 173
Coke, Sampling and Analysis 444
Commercial Aluminum 170
Commercial Hydro-Fluoric Acid 51
Commercial Thorium Nitrate 435
Converting Sulphates to Chlorides 39
Copper 49
Copper by the Iodide Method 45
Copper Sulphide 44
Cyanide Process 174
Cyanide Process for Copper 44
Cyanide Solutions 443
Decomposition of Silicates by Boric Acid 54
Degree of Oxidation of Oils 57
Detecting Boric Acid in Milk, Wine, etc. 54
Detecting Iodine in presence of other Halogens 50
Determination of Bismuth 172
Determination of Chlorides, Hypochlorides, Chlorates and Perchlorates 50
Determining Hydrogen by Palladivus Chloride 57
Determining Nitric Acid 56
Determining Selenious and Selenic Acid 48
Determining Zinc as Zinc Sulphate 434
Electrolysis of Solutions Containing Manganese and Tin 48
Electrolytic Determination of Cadmium 437
Electrolytic Determination of Iron, Nickel and Zinc 48
Electrolytic Determination of Lead 172
Electrolytic Separations 49
Estimating Oxygen by Pyrogallol Solution 56
Estimation of Cyanogen 443
Formaldehyd as a Reagent with Oxydized Halogens 438
Glass, Attacked by Magnesia Mixture 39
Gold in Sea Water 171
Gold and Silver in Ores 438
Graphitic Silicon 41
Halogens: Indirect Determination 49
Hydrochloric Acid Gas in Metal Separations 169
Hydrogen Peroxide in Titrating Iron 433
Insoluble Phosphorus in Iron Ores 439
Iron 49
Iron and Alumina in Phosphate Rock 40
Iron containing Boron 443
Lead and Copper in Waters 173
Lead in Ores 437
Lime and Sulphuric Acid 39
Lucium 176
Manganese Alloy 42

Manganese in Steel 43
Mercury by Sodium Peroxide 45
Mercury in Ammonio-Mercuric Chloride 438
Modification of the Gunning Method for Nitrates 174
Molybdenum 49
Molybdic Acid by Iodometric Method 435
Monazite Sand 436

New Element 176, 444
New Reagent for Hydrogen Peroxide 57
Nickel Alloys 41
Nickel and Zinc as Phosphates 434
Nitrates in Water 56
Nitric Nitrogen 443
Nitrous Acid in presence of Sulphites 174
Nitrous Acid Reaction 443

Ordinary Mortars 58
Oxygen in Commercial Copper 45
Oxygen in Water 56
Ozone and Hydrogen Peroxide 57

Persulphates 53
Phosphates in Coal 173
Phosphates in Fertilizers 54
Phosphates in Thomas Slag 54
Phosphates in Water 440
Phosphides of Chromium and Manganese 433
Phosphor Bronze 440
Phosphorus by Iodometric Method 439
Phosphorus in Phosphor Bronze 53
Platinum Sulphide 438
Potassium Determination 431
Potassium Estimation 431
Properties of Some Metallic Sulphates 439
Pyrrhotite in Pyrites 52

Rapid determination of Manganese in Ores 43
Recovering Platinum from Waste Solutions 430
Reducing Potassium Platin-Chloride 48

Selenium, Gravimetric Determination 436
Selenium, Gravimetric Estimation 48
Separating Aluminum from Iron 170
Separating Chlorine and Bromine 439
Separating Manganese from Tungstic Acid 173
Separating Nickel from Cobalt, Iron, etc. 433
Separating Silicic and Tungstic Acid 435
Separating Thoria from Zirconia 435
Separating Tungsten from Titanium 434
Separation for Thorium 173
Separation of Barium, Strontium and Calcium 432
Separation of Copper 44
Separation of Lead and Bismuth 172
Silicates 442
Silica in Blast Furnace Slags 442
Silicon in Silico-Spiegel and Ferro-Silicon 442
Silver 49
Sodium 41
Sodium Peroxide as a third Group Reagent 439
Solubility of Barium Sulphate 53, 170
Soluble Phosphates in Fertilizers 439
Soluble Silica in Clays 55
Spectrographic Analysis 39
Standardizing Permanganate 170
Standardizing Permanganate and Sulphuric Acid 39

Standard Oxalic Acid Solutions 430
Sulphates 53
Sulphides 53
Sulphides, Sulphites, Thiosulphates and Sulphates in presence of each other.. 53
Sulphites and Thiosulphates 53
Sulphur in Illuminating Gas and Coal..... 52
Sulphur in Irons 174, 441
Sulphur in Iron or Steel..... 173
Sulphur in Pig Iron 52, 441
Tests for Nitrites..... 56
Titanic Acid 433
Titanium Alloy..... 42
Tungsten Alloy 42
Uranium 49
Volatility of Salts 430
Volhard's Method for Manganese..... 43
Volumetric for Arsenic..... 47
Volumetric for Copper..... 44
Volumetric for Iodine 51
Volumetric for Lead.....45, 172
Volumetric for Nickel..... 433
Volumetric for Phosphoric Acid..... 54
Volumetric for Zinc..... 434
Water, Test for Contamination..... 57
Zinc Alloy 42
Zinc Dust..... 434

Apparatus for the Measurement of the Indices of Refraction of Small Crystals by the Method of Total Reflection. A. J. Moses and E. Weinschenck..... 13

BOOK REVIEWS.....59, 176, 296, 445
Alternating Currents and Alternating Current Machinery. D. C. Jackson, C. E., and J. P. Jackson, M. E..... 178
Cell in Development and Inheritance, The. Edmund B. Wilson, Ph. D... 184
Chemical Analysis of Iron, The. Alexander A. Blair..... 59
Colorado, Bulletin, State Agricultural College..... 183
Colliery Surveying. T. A. O'Donahue..... 181
Davy, Humphrey. T. E. Thorpe, D.D., F. R. S..... 64
Dictionary of the Names of Minerals, A. Prof. Albert H. Chester..... 446
Elementary Geology. Ralph S. Tarr..... 300
Elementary Solid Geometry and Mensuration. Henry Dallas Thompson, D. Sc., Ph. D..... 61
Elements of Geometry. Andrew W. Phillips, Ph. D..... 183
Elements of Mineralogy, Crystallography and Blowpipe Analysis. Alfred J. Moses and Chas. Lathrop Parsons..... 302
Elements of Physics, Vol. II., Electricity and Magnetism. Edward L. Nichols and William S. Franklin 62
Elements of Physics, Vol. III., Light and Sound. Edward L. Nichols and William S. Franklin..... 446
Gases of the Atmosphere, The. William Ramsey, F. R. S..... 178
Manual of Quantitative Chemical Analysis. Frederick A. Carins. Revised by Elwyn Waller, Ph. D..... 60
Materials of Construction. J. B. Johnson, C. E..... 298
Mechanical Engineering of Power Plants. Frederick Remsen Hutton, E. M., Ph. D..... 296
Mechanics of Pumping Machinery. Dr. Julius Weisbach and Prof. Gustav Hermann..... 179
Metals, Their Properties and Treatment. A. K. Huntington and W. G. McMillan 301
Missouri Geological Survey. H. A. Wheeler..... 445
Notes on Assaying. P. De Peyster Ricketts, E. M., Ph. D., and Edmund H. Miller, A. M., Ph. D..... 176

Preliminary Report on the Clays and Clay Industries of the Coal and Coal-bearing Counties of Indiana. W. S. Blatchley..... 65
Primer of the Calculus. E. Sherman Gould..... 445
Problems and Questions in Physics. Chas. P. Matthews..... 302
Röntgen Rays and Phenomenon of the Anode and Cathode. Edward P. Thompson..... 63
Tables showing Loss of Head due to Friction of Water in Pipes. Edmund B. Weston, C. E..... 299
Text-Book of Plane Surveying. William G. Raymond, C. E..... 182
Theory of Solution and its Results. J. Livingston R. Morgan..... 299
Trigonometry for Beginners. Rev. J. B. Lock, M. A..... 61
Calculation of Copper Matte, Blast Furnace Charges, The. H. Van F. Furman..... 1
Correction in Article on Calculation of Copper Matte Blast Furnace Charges.... 167
Crocker, Francis B. *Principles of Electrical Distribution*.....93, 240, 366
DEPARTMENT NOTES..... 66
Details of Modern Water Works Construction. Wolcott C. Foster..... 154
DEVEREUX, W. B. *Notes on the Western Practice of Metallurgy—Economically Considered*..... 348
Devereux Prize..... 288
Dudley, P. H. Undulations in Railway Tracks..... 119
Egleston Minute of the Alumni Association of the School of Mines..... 193
Explorations in the Gold Fields of Western Colombia..... 259
FOSTER, WOLCOTT C. *Details of Modern Water Works Construction*..... 154
FREEDMAN, W. H. *The Secohmmeter as Used in the Electrical Engineering Laboratory*..... 29
FURMAN, H. Van F. *The Calculation of Copper Matte Blast Furnace Charges*..1–167
HALLOCK, W. *Subterranean Temperatures at Wheeling, W. Va., and Pittsburg, Pa*..... 148
HAMLIN, A. D. F. *The Modern Dome*..... 109
Hints to Students of Irrigation Engineering. A. M. Ryon..... 161
Hydrographic Surveys in Montana. A. M. Ryon..... 23
ILES, Malvern W. *Wall Accretions of Lead Blast Furnaces*..... 18
Introduction to the Study and Experimental Determination of the Characters of Crystals. Alfred J. Moses, Ph.D.....266–385
Metallurgy, Abstracts in, by Joseph Struthers, Ph. D 289
Aluminum..... 296
Bessemer Steel..... 293
Blast Heating..... 290
Copper..... 294
Forge and Mill Work..... 292
Foundry Practice..... 291
Fuels..... 289
Gas Producers..... 290
Gold..... 295
Iron and Steel Industries, The..... 292
Lead..... 294
Malleable Iron..... 291
Mercury and Tin..... 296
Open Hearth Steel..... 292
Ores of Iron..... 290
Pig Iron, Blast Furnace Practice..... 290
Pig Iron, Properties..... 291
Pyrometry..... 289

Refractory Materials 289
Steel 293
Silver 294
Modern Dome, The. A. D. F. Hamlin 109
MOSES, ALFRED J., Ph. D., *An Introduction to the Study and Experimental Determination of the Characters of Crystals* 266–385
MOSES, ALFRED J., Ph. D., and WEINSCHENCK, E., *A Simple Apparatus for the Measurement of the Indices of Refraction of Small Crystals by the Method of Total Reflection* 13
NICHOLAS, F. C., *Explorations in the Gold Fields of Western Colombia* 259
Notes on the Present Western Practice of Metallurgy—Economically considered,. W. B. Devereux 348
Oil Machine, The. George Richmond 135
PEELE, ROBERT, *Notes on Air Compressors* 196–309
PEELE, ROBERT, *Preliminary Hoisting Plant for Mines* 85
Preliminary Hoisting Plant for Mines, Robert Peele 85
Principles of Electrical Distribution. Francis B. Crocker 93, 240, 366
Professional Draughtsmen as Special Students in the School of Architecture. William R. Ware 422
Puzzolana and its Practical Use. Josef Zervas 226
RICHMOND, GEORGE. *The Oil Machine* 135
RYON, A. M. *A Few Hints to Students of Irrigation Engineering* 161
RYON, A. M. *Hydrographic Surveys in Montana* 23
Secohmmeter as used in the Electrical Engineering Laboratory, The. W. H. Freedman 29
Subterranean Temperatures at Wheeling, W. Va., and Pittsburg, Pa. W. Hallock 148
STRUTHERS, JOS., Ph. D., *Abstracts in Metallurgy* 289
Undulations in Railway Tracks. P. H. Dudley 119
Wall Accretions of Lead Blast Furnaces. Malvern W. Iles 13
WALLER, ELWYN, Ph. D., *Abstracts in Analytical Chemistry* 39, 169, 430
WARE, WILLIAM R., *Professional Draughtsmen as Special Students in the School of Architecture* 422
WEINSCHENK, E., *A Simple Apparatus for the Measurement of the Indices of Refraction of Small Crystals by the Method of Total Reflection* 13
ZERVAS, JOSEPH. *Puzzolana and its Practical Use* 226

Vol. XVIII. No. 1. NOVEMBER, 1

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CONTENTS:

The Calculation of Copper Matte Blast Furnace Charges. By H. Van F. Furman. ....
A Simple Apparatus for the Measurement of the Indices of Refraction of Small Cryatals by the Method of Total Reflection. By A. J. Moses and E. Weinschenk ....
Wall Accretions of Lead Blast Furnaces. By Malvern W. Iles ....
Hydrographic Surveys in Montana. By A. M. Ryon, E. M. ....
The Secohmmeter as Used in the Electrical Engineering Laboratory. By W. H. Freedman, C. E., E. E. ....
Abstracts in Analytical Chemistry. By Elwyn Waller, Ph. D. ....
Book Reviews ....
Department Notes ....
Alumni and University News....

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HE CALCULATION OF COPPER MATTE BLAST-FURNACE CHARGES.

By H. VAN F. FURMAN.

he few years ago the writer published a paper in the QUAR-* entitled "The Calculation of Lead Blast-Furnace Charges." resent article may be regarded as a supplement to the former and has been written more for the student than for the practical urgist who is, presumably, familiar with these elementary tions.

problem is not simple owing to the continually varying ions and the many different points which must be considered, ost important being as follows:

. The charge must be calculated so as to produce a slag will be good both from a metallurgical and an economic oint. A good metallurgical slag is one which is fusible, is d to the ores to be smelted, should keep the furnace in good ion, should allow a good separation of the matte, and hence have as low a specific gravity as possible, should be low in opper and silver, and should usually permit of a high degree centration of the copper into the matte. An economic slag which will fulfill the above conditions and at the same time n economic mixture of the ores to be treated so that a mini-

mum amount of costly fuel and flux will be required. The addition of flux to the furnace charge not only increases the smelting cost, as for each pound of flux required one pound less of ore can be treated, thus involving an additional labor and fuel expense for the ore smelted; but it diminishes the available capacity of the plant.

In copper matte smelting the percentage composition of the slag is not of the same importance as in lead smelting where the metallurgist is restricted to certain type slags of fixed chemical composition. The lead smelter must adhere to these types, which have been well established, in order that economical work may result. The copper metallurgist is simply restricted within rather wide limits as regards the percentages of slag producing elements which may be present. While the type slags of the lead smelter may be used in copper smelting, they are generally uneconomical as they are quite basic and require a large amount of flux for their production. They fulfill all the requirements of a good metallurgical slag, but in most localities can not be produced without the addition of considerable limestone, and possibly other fluxes, to the charge.

The limits of the principal slag constituents in copper matte smelting may be stated as follows:

SiO_2	26 to 45%.
Al_2O_3	0 to 20%.
FeO	28 to 65%.
CaO	0 to 28%.
ZnO	0 to 14%.

In this table MnO is regarded as replacing FeO, and BaO and MgO as replacing CaO. Manganese replaces iron and renders the slag extremely fusible; but Iles * considers manganese as detrimental on account of its tendency to carry silver into the slag. Church,† however, does not consider manganese as detrimental and claims to have made slags containing over 43% MnO which were remarkably low in silver (0.5 oz. per ton).

The presence of MgO and BaO in copper slags is not as objectionable as in lead slags where under 4% of either oxide is generally regarded as the safe limit. Copper matte slags have

* School of Mines Quarterly, Vol. V., p. 217.

† Trans. Am. Inst., M. E., Vol. XV., p. 612. School of Mines Quarterly, Vol. V., p. 322.

been successfully run with as much as 12% of these oxides. The presence of BaO is objectionable as it raises the specific gravity of the slag. The presence of zinc is objectionable in both lead and copper smelting, as it has a tendency to render the slag thick and infusible and consequently increases the slag loss in valuable metals. It also has a marked tendency to increase the loss of silver by volatilization during the roasting or smelting operations. In lead smelting 13% of ZnO in the slag may be regarded as the maximum limit, but in copper smelting slightly higher limits have been reached. All slags contain other constituents as, Na_2O, K_2O. PbO, Cu_2S, CaS, etc., which are generally present in small quantities, so that the sum of the SiO_2, FeO, MnO, CaO, ZnO and Al_2O_3 may be taken as forming from 90 to 95% of the slag, except when much MgO or BaO is present. The action of alumina in these slags has been the subject of much speculation and discussion and more exact information on this important question is needed. In the highly ferruginous slags of the lead and copper smelter alumina usually plays the part of an acid, but slags are occasionally encountered in which the alumina is present as a base.

The specific gravity of the slag is an important point. The loss of silver and copper in the slag will depend largely upon the difference in specific gravity of the matte and slag. The specific gravity of the ordinary matte may be stated as from 5.0 to 5.5, whilst that of the slag is from 3.5 to 3.75. It is essential that a considerable difference in specific gravity (1.75 about) should exist between the matte and slag in order that a good separation may be affected. Of course, the greater the difference, other things being equal, the more perfect the separation.

Second. The furnace charges must be arranged so as to use up the ores on hand and the daily supply in about the proportions in which they exist. This requires that the ore buyer, or mine superintendent, and the metallurgist should keep in touch with each other and be familiar with the requirements of each.

Third. The charges must be calculated, as near as possible, so that the resulting matte will be of the proper grade for shipment or for its further metallurgical treatment at the works. This is frequently a question of great importance, as, for example, suppose the matte is to be treated for blister copper by bessemerizing at the works. In the United States it has not so far proven profita-

ble to bessemerize mattes containing much less than 50 % copper. When the matte is shipped to a distant refining works for further treatment the freight and refining charges are items which cannot be disregarded in the calculation of what will be the most profitable grade of matte to produce. The percentage of copper in the furnace charge and the fall of matte will also have an influence on the loss of silver and copper in the smelting operation.

Fourth. The amount of sulphur, arsenic and antimony which will be volatilized in smelting is of the greatest importance and upon this many of the other questions will depend to a large extent. This has a direct influence on the rate of concentration, the grade of the matte and the consumption of fuel, all questions of vital importance. This factor is extremely variable the amount volatilized being from 8 % in ordinary matte smelting, to probably 90% in true pyritic smelting. It depends upon the construction and operation of the furnace and upon the physical and mineralogical character of the ores. Depending upon so many variable considerations it is impossible to formulate any rule which will serve as more than a guide in the calculation. A safe rule can only be arrived at after the furnace has been in operation for some time and after numerous experiments have been made. Even then no absolute rule can be formulated as conditions will necessarily vary from time to time. In connection with this question it should be remembered that for pyritic smelting the amount of sulphur consumed by oxidation must be large. True pyritic smelting requires at least 65% of pyrites, or equivalent sulphides or arsenides, on the furnace charge in order that suffiicient heat may be generated to smelt the mixture. It is true that partial pyritic smelting is successfully carried on with a smaller percentage of pyrites, using carbonaceous fuel in the furnace, and limestone as a flux to supply the deficiency in basic elements on the charge.

Fifth. The character, or chemical composition, of the resulting matte must be considered. This will depend upon the mineralogical character of the ores, the volatilization of sulphur, arsenic, antimony, zinc and lead, the operation of the furnace and the character of the resulting slag. As these are all variable no exact rule can be formulated for the determination of this question. Until the works have been in operation for a sufficient time, so that the

question can be settled by frequent analyses of the matte, the following rule will serve as a guide:

1. From the total S, As and Sb on the charge, deduct such amount as will probably be volatilized (in ordinary matte smelting this may be taken as 10%). The balance is to be considered as S, etc., available for matte.
2. Calculate all of the copper present to Cu_2S.
3. Calculate three-quarters of the lead present to PbS.
4. Calculate one-half of the zinc present to ZnS.
5. Calculate the remainder of the available sulphur to FeS.

These sulphides will usually constitute from 90 to 95 % of the matte. The remainder will be slag mechanically mixed with the matte, probably metallic iron, and other sulphides, arsenides and antimony compounds. The matte may also contain sulphides and arsenides other than the simple ones enumerated. The true composition of matte has never been accurately determined and a thorough investigation of the subject would be of great benefit to modern metallurgy.

The calculation is illustrated by the following example:

ANALYSIS OF ROASTED ORE.

SiO_2	25%
Fe	46%
Cu	10%
Zn	4.5%
Pb	3%
S	7%

Assuming that 10% of the sulphur will be volatilized, we have 6.3 parts of sulphur available for matte in each 100 parts of ore.

Mol. Wt. Cu_2	:	Mol. Wt. Cu_2S	=	Parts Cu	:	Parts Cu_2S.
126	:	158	=	10	:	12.54.
At. Wt. Pb	:	Mol. Wt. PbS	=	¾ Parts Pb	:	Parts PbS.
207	:	239	=	2.25	:	2.59.
At. Wt. Zn	:	Mol. Wt. ZnS	=	½ Parts Zn	:	Parts ZnS.
65	:	97	=	2.25	:	2.35.

The sum of these sulphides is 18.48 parts. This less the sum of the metals (14.5) leaves 3.98 parts of sulphur, which combine with

the Cu, Pb and Zn, leaving (6.3 — 3.98) 2.32 parts of sulphur to combine with the iron.

At. Wt. S	:	Mol. Wt. FeS	=	Parts S	:	Parts FeS.
32	:	88	=	2.32	:	6.38.

If we assume that the C_2S, FeS, PbS and ZnS constitute 90% of the matte, for the parts of matte produced, we have

$$\frac{18.48 + 6.38}{0.9} = 27.6.$$

and for the percentage of copper in the matte

$$27.6 : 10 = 100 : x; \; x = 36.2\%.$$

This figure is too high, as no allowance has been made for loss of copper in the slag.

The next step in the calculation is to determine whether sufficient iron is present to form a good slag. For iron available for slag we have 46 — (6.38 — 2.32) or 41.94 parts, which is equal to 53.9 parts FeO. If we assume that the SiO_2 and FeO constitute 90% of the slag, we have

$$\frac{25 + 53.9}{0.9} = 89.66 \text{ parts of slag produced.}$$

Its composition is as follows:

$$\frac{25 + 100}{87.66} = 28.5\% \; SiO_2$$

$$\frac{53.9 + 100}{87.66} = 61.5\% \; FeO.$$

This shows the resulting slag to be somewhat high in iron and low in silica. This might be obviated by leaving more sulphur in the roasted ore, which would result in a larger amount of iron going into the matte, or should silicious ores be available, sufficient silica in the form of ore could be added to produce a slag of the proper composition. The necessary fuel to be added to the charge will also supply some of the deficient silica.

Sixth. The furnace charge should have the proper weight, which will depend principally upon the size of the furnace and somewhat

upon the character of the ores. The weight of the charge will have a direct bearing upon the practical working of the furnace. It will vary from 2,000 to 4,000 pounds according to the conditions, the proper weight having to be determined by actual experiment in each individual case.

Seventh. The amount of fuel to be added to the charge and the amount and composition of its ash are important points. The amount necessary will depend upon its character, the character of the ores, the composition of the slag and the operation of the furnace. In ordinary matte smelting, where only a small percentage of the sulphur present is volatilized, from 10 to 15% of good coke will be required. By fuel percentage is understood a percentage of the ore and flux charge. This estimate is based upon a good, firm, porous coke containing about 12% ash. As the percentage of ash increases, or the quality of the coke deteriorates, the amount used must be increased. As the amount of sulphur, arsenic or antimony volatilized increases, the percentage of carbonaceous fuel required decreases, until in the case of true pyritic smelting no carbonaceous fuel is added to the charge, the combustion of the sulphur, arsenic, etc., together with the hot blast introduced at the tuyères, supplying the necessary heat units.

Eighth. The loss of gold, silver and copper in the smelting operation demands consideration. These losses will vary according to the grade and character of the ores and matte, the character of the slag, the operation of the furnace, and the facilities provided for the collection of flue dust and fume. In true pyritic smelting, the operation being one of oxidation, the losses will be greater than in ordinary matte smelting where the action is reduction. The presence of copper in the charge will have a marked effect on the gold and silver losses, even small amounts having a marked tendency to increase the concentration of the precious metals in the matte. In ordinary matte smelting the loss in gold should be practically *nil* and the silver loss should not exceed 5% of the assay value of the ore. The copper loss will depend principally upon the amount and character of the slag produced. With ordinary mattes, containing as much as 40% copper, a good slag should not contain over 0.6% copper. Under exceptional commercial conditions it may prove profitable to make slags assaying considerably higher, but in good work, and under ordinary conditions, the slags rarely exceed 0.5%. The amount

of zinc present may largely effect the gold and silver losses. The zinc oxide which is volatilized invariably carries off mechanically both gold and silver. These losses may be reduced by the introduction of proper dust and fume saving apparatus, but cannot be entirely obviated. Zinc also makes bad slags and hence increases the loss of gold, silver and copper in the slag. The production of a matte of as high, and a slag of as low, a specific gravity as possible, and the use of efficient settling and separating apparatus will also largely determine the losses.

The calculation of the charge is illustrated by the following examples:

Example No. 1. The works have a smelting capacity of 300 tons per 24 hours. Ore A, which is roasted, is practically unlimited in quantity coming from mines belonging to the smelting company. Ore B can be purchased to the extent of 75 tons per day and at a fair profit. The matte is shipped and sold to refiners. The assay of the ores is as follows:

Ore.	SiO_2%	Fe%	Cu%	Pb%	Zn%	S%	Al_2O_3%	CaO%	Ag. Ozs. per ton.	Au. Ozs. per ton.
A	25	46	10	3	3	7			15	0.5
B	50	5	3			2	10	12	50	0.1
Coke	6	1	(ash 10 %)				2	1		

Assuming that we will smelt about 250 tons of ore A and 50 tons of ore B per day, and want a furnace charge of about 3000 pounds we have, for pounds of each constituent of the charge:

Ore.	SiO_2 lbs.	Fe lbs.	Cu lbs.	Pb lbs.	Zn lbs.	S lbs.	Al_2O_3 lbs.	CaO lbs.	Ozs. Ag	Ozs. Au	Pounds per charge.
A	625	1150	250	75	75	175			18.75	0.625	2500
B	250	25	15			10	50	60	12.50	0.025	500
Coke	22	4					7	4			360
Total	897	1179	265	75	75	185	57	64	31.25	0.650	

Assuming that 10 % of the sulphur is volatilized, we have 166.5 pounds of sulphur available for matte. Calculating the copper to Cu_2S, two-thirds of the lead to PbS and one-half of the zinc to Zns, we have

$$\begin{aligned} 126 : 158 &= 265 \;\; : x;\; x = 332.3 \text{ lbs. } Cu_2S \\ 207 : 239 &= 50 \;\; : y;\; y = 57.7 \text{ lbs. PbS} \\ 65 : 97 &= 37.5 : z;\; z = 55.9 \text{ lbs. ZnS} \\ & \quad 352.5 \qquad\qquad 445.9 \end{aligned}$$

and 445.9—352.5 = 93.4 pounds of sulphur combining with the Cu, Pb and Zn. This leaves (166.5—93.4) 73.1 pounds of sulphur to be calculated to FeS. We have

$$32 : 88 = 73.1 : f;\; f = 201 \text{ lbs. FeS.}$$

Hence for iron available for slag we have 1179—(201—731) = 1,051 pounds. As some zinc, lead, copper, and small amounts of other elements which are usually present, pass into the slag the SiO_2, FeO, CaO and Al_2O_3 will usually form about 93 % of the slag constituents. Hence we have for the pounds of slag produced per charge:

$$\frac{897 + 1051 \times \frac{9}{7} + 57 + 64}{0.93} = 2547.$$

The composition or the slag will be as follows:

$$\frac{897 \times 100}{2547} = 35.2 \text{ \% } SiO_2.$$

$$\frac{1351 \times 100}{2547} = 53.0 \text{ \% FeO.}$$

$$\frac{57 \times 100}{2547} = 2.2 \text{ \% } Al_2O_3.$$

$$\frac{64 \times 100}{2547} = 2.6 \text{ \% CaO.}$$

This slag should run well and give a good separation of matte, but is somewhat high in iron and low in silica. Should a more acid slag be desirable it may be obtained by slightly increasing the amount of ore B.

Before calculating the amount and the composition of the resulting matte it is necessary to make allowance for the loss of copper in the slag. Assuming the resulting slag will assay 0.4 % copper, we have 10.2 pounds of copper to deduct from the total copper present, the remainder being that going to form matte. This is equivalent to 12.7 pounds of Cu_2S. If we assume that the Cu_2S, PbS, ZnS and FeS form 93 % of the matte, we have

$$\frac{(445.9 - 12.7) + 201}{0.93} = 682 \text{ lbs. of matte.}$$

The percentage of copper in the matte is

$$\frac{(265 - 10.2) \times 100}{682} = 37.3\ \%.$$

Allowing for a smelting loss of 5% silver and 1% gold, we have, for the assay of the matte:

$$\frac{29.6875 \times 2000}{682} = 87.06 \text{ ozs. Ag per ton.}$$

$$\frac{0.6435 \times 2000}{682} = 1.88 \text{ ozs. Au per ton.}$$

Example No. 2. We have the following ores to smelt, the capacity of the works being 300 tons per day. Ore A is purchased at a small profit and Stall roasted. Ores B and C are purchased at a good profit, and whilst ore C is a heavy sulphide the local conditions are such that it would be inadvisable to roast it. The matte is shipped and sold to refiners. The ores assay as follows:

Ore	SiO_2%	Fe%	Cu%	S%	CaO%	Pb%	Zn%	Ag. Ozs. per doz.	Au. Ozs. per ton.
A	10	55	12	7				5	0.3
B	90	5	1					15	1.0
C	15	25	5	35	5	4	6	20	0.5

Assuming that we smelt 200 tons of ore A, 50 tons of ore B and 50 tons of ore C per day and wish about 3000 pounds on the

furnace charge, we have, for the pounds of the different constituents on the charge:

Ore	lbs. SiO_2	lbs. Fe	lbs. Cu	lbs. S	lbs. CaO	lbs. Pb	lbs. Zn	Ozs. Ag	Ozs. Au	Pounds per charge.
A	200	1100	240	140				5.00	0.300	2000
B	450	25	5					3.75	0.250	500
C	75	125	25	175	25	20	30	5.00	0.125	500
Total	725	1250	270	315	25	20	30	13.75	0.675	3000

Calculating the Cu to Cu_2S, one-half the Zn to ZnS, two-thirds of the Pb to PbS and assuming that 80% of the sulphur is available for matte, we have

Cu_2S pounds	338.5
PbS "	15.3
ZnS "	22.4
FeS "	478.8
	855.0

Which leaves 1215 pounds of FeO available for slag. If the SiO_2, FeO and CaO form 90% of the slag we will have 2,183 pounds of slag produced per charge and its composition will be:

SiO_2	33.2%
FeO	55.6%
CaO	1.2%

This slag is slightly basic hence the weight of ore B might be increased to advantage. Using 700 of ore B, we will have 2,397 pounds of slag produced per charge and its composition will be:

SiO_2	37.8%
FeO	51.1%
CaO	1.1%

If the slag assays 0.5% copper and the Cu_2S, PbS, Zns and FeS constitute 93% of the matte, the percentage of copper in the matte should be 27.4. It should assay 32.6 ounces silver and 1.72 ounces gold per ton, assuming a 5% silver loss and no loss in gold.

Example No. 3. It is desired to erect a plant for the concentration of the copper and silver contained in an ore of the composition given into a matte for shipment. Upon roasting at a cost of $1. per ton the ore yields a product of the composition shown. With coke at $8. per ton the estimated cost of ordinary matte smelting of the roasted ore is $4. per ton, and the estimated cost of pyritic smelting of the raw ore is $3.25 per ton. Freight to the refining works on each ton of matte is $10. Which will be more profitable, ordinary matte or pyritic smelting?

	Raw Ore.	Roasted Ore.
SiO_2	15 %	17.5%
Fe	34 %	39.6%
Cu	4.1%	4.7%
CaO	3 %	3.5%
S	40 %	7 %
Ag	20 ozs.	23 ozs.

One ton of raw ore yields 1,720 pounds of roasted product. We will assume that in ordinary matte smelting 90% of the sulphur will pass into the matte, while in pyritic smelting only 20% of the sulphur is available for matte. Calculating the charges as before and assuming that the Cu_2S and FeS constitute 95% of the matte and that the SiO_2, FeO and CaO constitute 95% of the slag, we have,

	Pyritic Smelting.	Matte Smelting.
Matte produced per ton of crude ore,	511 pounds.	361 pounds.
Slag " " " "	969 "	1092 "
Copper in matte,	15.2%	21.6%
Cost of smelting per ton of crude ore,	$3.25	$3.44
" " roasting " " "		$1.00
Freight on matte " " "	$2.55	$1.82
Total cost,	$5.80	$6.26

The slags will have the following composition:

	From Pyritic Smelting.	From Matte Smelting.
SiO_2	30.9%	27.4%
FeO	57.9%	62.0%
CaO	6.2%	5.6%

The slag resulting from pyritic smelting is somewhat the best and should give a better separation of matte than that resulting from the matte smelting operation. Taking this fact, and also the loss of silver in roasting, into consideration the total losses will probably be about the same by either operation. With such an ore, under the conditions given, pyritic smelting would appear to be the cheapest process. However the difference of $0.46 per ton in favor of pyritic smelting would probably be more than offset by the refining charges on the increased amount of matte and in consequence of its lower grade.

A SIMPLE APPARATUS FOR THE MEASUREMENT OF THE INDICES OF REFRACTION OF SMALL CRYSTALS BY THE METHOD OF TOTAL REFLECTION.

By A. J. MOSES and E. WEINSCHENK.

Although the determination of indices of refraction by the method of total reflection requires only one natural or ground surface parallel to an axis of elasticity, and although the method is applicable even to twin crystals, or those showing parallel growths of different refractive power, provided only that the surface layer is homogeneous, yet the method is not generally employed by mineralogists because the large and perfect crystal surfaces required rarely occur and can be prepared only from a few minerals.

Of the two general methods the Kohlrausch employs a liquid of higher index of refraction than the substance tested, and, from variations in the liquid and the difficulty of exact orientation of the surface, is only applicable for approximate determinations; the other method, the Wollaston, which substitutes a surface of polished glass of high index of refraction with a drop of strongly refracting liquid interposed between the glass and mineral to displace the thin layer of air, permits of the determination of higher indices and is independent of the variations in the liquid employed, but requires large surfaces and the manipulation is difficult and tedious.

The problem, therefore, is to provide an apparatus easily manipulated, accurate and rapid in adjustment, not injuriously affected

by the heat of the flame used, and available for small faces; these advantages we claim for the apparatus here described and figured.

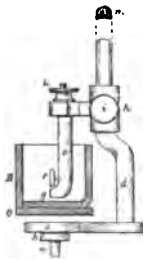

FIG. 1.

FIG. 2.

The apparatus is constructed as an attachment to the Fuess No. 2 Goniometer. Figs. 1 and 2 show the crystal carrier, the pin *a* fits in place of the pin of the usual crystal plate of the instrument the collar *b* insures a firm bearing and provides space below *c* for the rimmed asbestus plate, shown in Fig. 5, forming the bottom of the box. The brass piece *c* carries a bent steel rod *d*, the vertical upper portion of which* has the section shown at *m*. Upon *d* slides the horizontal arm *h* which may be clamped at any desired height by the screw *i*. Through the arm *h* passes a vertical rod *e* which, by loosening the screw *k*, may be turned as desired, *e* is split vertically from below, and one side is made longer than the other, and bent as shown at *g* to serve as a carrier for the control mineral.

The mineral to be tested is fastened to the little square plate *f*, and the pin of this is thrust into a hole in the split rod *e*, which holds it as in a spring and it can be easily turned in its own plane as desired. The plate *f* and the end *g* are cross hacked for the better adhesion of the mineral.

The little glass vessel *B*, (Figs. 1 and 3) for holding the refracting liquid, consists of a plane parallel glass front glued† to a little cylinder which has been ground off to fit it. The vessel is supported by the metal arm *A* (Fig. 3) which is attached to the supporting column of the observation telescope by a screw and two little pegs.

* In a second apparatus *d* is made straight and *h* longer.

† A solution of isinglass in acetic acid resists the solvent action of the liquids very well.

FIG. 3.

It is essential that the centre of this vessel shall be closely in the centre of rotation and that the front plane surface shall be accurately and permanently perpendicular to the axis of the telescope. This adjustment is made as follows: In Fig. 4 the larger circle represents the Fuess instrument and the smaller circle the vessel. The collimator is at *A*. The distance from the centre of the vessel to the plane front is measured, and a plate of glass (conveniently a cover glass) is fastened vertically on the crystal plate of the Fuess instrument, centered and then made eccentric a distance equal to that measured. The telescope is then clamped opposite the collimator, the plate turned to some position *a b* and a reading made. Then with the circle clamped the telescope is turned till the signal from the glass plate is visible (*i. e.*, to *B*) then further through an arc *BC* equal one-half the supplement of the measured angle and there clamped. With another telescope not attached to the apparatus the signal from *a b* is again found, the glass plate removed, the arm screwed on, the vessel glued to it and during the hardening of the glue the vessel adjusted so that a signal from its plane front reaches the auxiliary telescope and its centre is approximately in the centre of rotation.

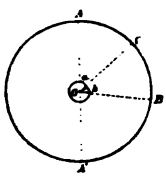

FIG. 4.

A disc of metal pierced for the rod *e* may be used as a cover for the vessel, the upper edge of which is then smeared with grease, but it does not appear to materially affect the results.

For maintaining a fairly constant temperature unaffected by the mass of metal in the Fuess instrument, the crystal carrier and the glass vessel are covered by a cylindrical box Fig. 5 of asbestus lined with thin card. The box is pierced at the top by a thermometer reading from 0° to 50°C. At the proper height an opening is made for the telescope and another, extending over half way around, for the admission of light. The latter opening is covered with a glass which is curved to fit. The box is held in position by a metal band and arm which clips the telescope as

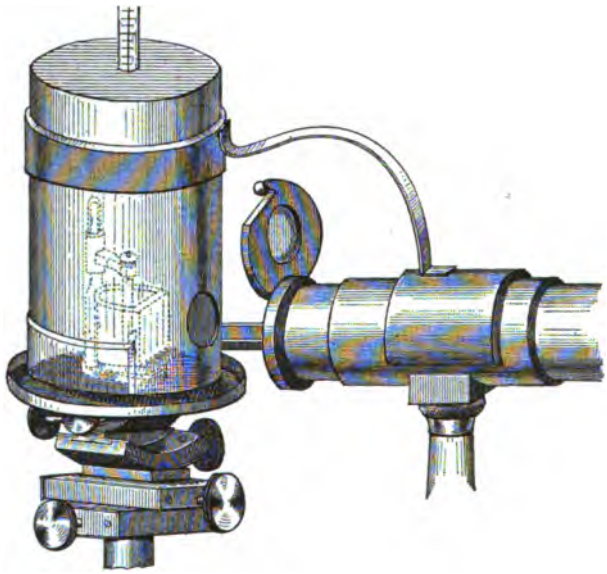

FIG. 5.

shown in Fig. 5. Beneath the box and serving as a bottom is a round plate of asbestus paper with a rim, it rests npon the centreing apparatus below *c* Fig. 1. The space between the rim and box is packed with asbestus or cotton wool.

The process of measuring is as follows: The apparatus is arranged by the eye so that the necessary rotation can be secured and so that the crystal face is approximately oriented, then the exact adjustments are made by the Fuess telescope and centering screws. The little vessel is then filled with the refracting liquid, the asbestus box fixed in position, the light adjusted, the total reflection boundary found and brought to coincidence with the cross hairs and the apparatus left with all lights burning for one-half hour as the readings are valueless until the approximately constant temperature has been attained. The boundary is then recentered and a reading made. The readings are repeated at intervals until constant, then the light is moved to the other side and the other readings obtained. The control mineral (*g* Fig. 1) is then raised into the field, centered and adjusted accurately without in any way disturbing the vessel or asbestus box and the readings for this are obtained in the same manner.

From these readings the index of refraction of the mineral tested is calculated directly by the simple formula:

$$n = n' \frac{\sin i}{\sin F}$$

in which

i = half the angle of rotation of the mineral tested.
F = " " " " " " " control mineral.
n' = index of refraction of the control mineral.

The refracting liquid used may be: Thoulet solution, Rohrbach solution, α mono-Bromnapthalin, Methylene iodide alone or saturated with iodoform or sulphur, or any other sufficiently stable and transparent liquid the index of refraction of which is higher than that of the mineral to be tested.

For a control mineral fluorite is very suitable as its refraction has been very carefully determined,* and further, as it is isotropic, has a low index of refraction and is easily obtained.

We claim that the apparatus has the following advantages: 1°. A rapid and accurate adjustment first by the eye then by the Fuess telescope and adjusting screws. 2°. That the asbestus box makes possible the maintenance of a constant temperature. 3°. That by the use of a control mineral the errors due to variations in the liquid are eliminated. 4°. That very small faces can be used because there is very little light lost and there are no interfering boundaries from other surfaces.

As proof of the justice of these claims we submit the following examples:

A prism face on a quartz crystal from Middleville, N. Y., with an area of two square millimeters, tested in methylene iodide (CH_2I_2) with the sodium flame gave.

Time of Observation.	Temperature.	Reading.		
8.35 adjusted.				
9.05	29°	ε	262°	30'.5
"	28.7	ω	261	49.5
9.35	28.2	ε	262	30
"	28.	ω	261	49
"	28	ε	135	40
"	28.2	ω	13.6	18.5
10.00	30	ε	135	37
"	29.8	ω	136	17

* See Landolt and Börnstein *Physikalisch-Chemische Tabellen* 385.

From this resulted $i_\epsilon = 116° 35'$ $i_\omega = 117° 114'¾$.

The control mineral (Fluorite) yielded $F = 124° 20'¼$ and assuming the index of refraction with sodium flame to be 1.43390 and substituting in the formula

$$\epsilon = 1.5530 \quad \omega = 1.5438$$

These results compare well with the best of those by the prism method.

To test the accuracy with very small faces a narrow face of a little quartz crystal from the Scheelite locality at Riesengrund was tried. The face was approximately 1½×½ mm. and fairly bright. From this we obtained

$$i_\epsilon = 116° 41¼ \; i_\omega = 117° 22½$$

from which resulted

$$\epsilon = 1.5515 \quad \omega = 1.5420.$$

Results sufficiently close to be satisfactory, though not equal to those from the larger surface.

MUNICH, February 27, 1896.

WALL ACCRETIONS OF LEAD BLAST FURNACES.

BY MALVERN W. ILES.

In the metallurgical treatment of all metals in furnaces designated as blast furnaces or cupola furnaces, there will ultimately be found accumulations upon the side-wall of these furnaces. The rapidity with which these accretions occur, varies very greatly, in accordance with the nature of the substances treated, and the manner of conducting the work. Generally speaking, such substances which are found to be volatile or which are susceptible of sublimation from the internal heat of the furnace, are most prone to cause these obstructions which are known by the lead smelter as "*hangings*."

There never has been discovered anything which will prevent these furnace hangings, and from the very nature of things there never will be, since all metals and metalloids, when subjected to certain given conditions, such as the reducing influences, likewise the oxydizing influences of a blast furnace will always deport themselves in accordance with certain immutable laws of chemistry.

Much thought and experimentation has been given to these wall accretions by metallurgists with a view of entirely preventing them; this will never be done in the opinion of the writer, since it necessarily involves a change in the laws of Nature.

We, however, have this subject, to a certain extent under our control, and we can increase or decrease these troubles by a proper comprehension of the subject.

By a careful examination into the causes which produce these so-called hangings, we are led to make the following statements with reference thereto: Zinc, in its various forms and combinations; is one of the chief causes of these accumulations. Generally speaking, by an increase in the amount of zinc, we will increase our troubles; yet certain salts of zinc are more troublesome than others, for example, the carbonate of zinc gives the least trouble, whilst the sulphide of zinc gives the most trouble; particularly is the sulphide troublesome when associated with galena and in a fine state of division.

All substances which produce these hangings increase the rapidity of the hanging according to the *size of the particles*, the finer the particle the more rapid will the hangings grow or accumulate.

Zinc occurs in these hangings nearly always as a sulphide, yet in the lower portions of the furnace, where there is a direct impingement of the blast, it is common to find a certain limited amount of zinc oxide.

The amount of zinc which occurs in these hangings, according to the experience of the writer, for a period of seventeen years, and which includes a great variety of forms in the furnace, likewise a great variety of conditions, has a range of 5.3 to 63.8%.

The general average of all determinations during this period is 18.42%.

This average was determined by sampling down the entire amount of accumulation which occurred upon the walls above the water-jackets which rested upon the furnace crucible.

Experience has shown that it is not best to use any scrap-iron upon heavy zinc charges, since it is well known that heated metallic iron will decompose zinc sulphide, and yet some of the best results have been obtained by the formation of slags containing considerable iron, existing as a silicate of protoxide.

Care should always be taken to lessen the amount of calcium oxide, just in accordance with the amount of zinc which enters the charge.

Where one is passing much zinc into the slags as a silicate, constant watchfulness is necessary to carry a proper amount of the alkaline earths, and to use extreme care not to use too much.

One pound of ZnO is equivalent to 0.691 pounds of CaO. That is to say, when one is producing a slag composed essentially of a silicate of iron, lime and zinc; then as the zinc increases in amount we should lessen the amount of lime, according to the saturating effect it has upon silicic acid, namely, that one pound of CaO will saturate as much silica as 0.691 pounds of ZnO.

It is simply wonderful how rapidly hangings will accumulate if one uses too much alkaline earths in the presence of much zinc.

As zinc is the chief cause for the hangings occurring on the furnace walls of lead smelters, we deem it a matter of much importance to fully recognize the fact, that just as the amount of zinc increases upon the charge, so also should the amount of lime be lessened upon the charge.

The following little table has been of great aid to us, viz:

	CaO. Equivalence.
1 pound	Al_2O_3 = 1.631 pounds CaO.
1 "	MgO = 1.400 " "
1 "	Fe_2O_3 = 1.050 " "
1 "	Zn = 0.861 " "
1 "	FeO = 0.780 " "
1 "	MnO = 0.780 " "
1 "	CuO = 0.704 " "
1 "	ZnO = 0.691 " "
1 "	BaO = 0.365 " "

In order to see what are some of the other causes for furnace hangings, aside from zinc, I will give the average of all determinations which I have been able to accumulate upon these barrings, viz:

17.26 % SiO_2
13.26 " Fe.
1.60 " Mn.
3.30 " CaO.
10.90 " S.
18.42 " Zn.
0.80 " Cu.

The fire assay gave as a general average of 17 years tests:

29.74 oz. Silver per ton (2000 pounds).
24.06 % Lead.
0.197 oz. Gold per ton (2000 pounds).

By physical and chemical tests, we have found the silica to exist both as free silicic acid, which has become mechanically lodged in these hangings, and also some mechanically lodged silicates; in addition to this the writer believes that there is a certain small amount of silicates formed within the furnace which becomes baked upon and into the hangings. The iron exists in the hangings as silicate, oxide and sulphide. The sulphide enters into the hanging as a true constituent and is a potent factor for the cause of these accretions, whilst the silicate and oxide are, we believe, merely accidental or incidental.

Manganese exists in the form of a silicate, or ore which has become entangled into the hanging by entering from the top ledge of the hanging.

The CaO exists generally as such, free and uncombined; there is some little lime existing as a silicate from mechanically lodged slag, but as a sulphide there is the merest trace.

The sulphur is present chiefly as a sulphide of zinc and lead, and this forms the main mass of these hangings. There is always some sulphate as a resultant of the oxidation of the sulphides of zinc, lead and iron. We have already spoken of the condition zinc exists in these hangings. Copper is small in amount and does not play an important part, but is known to exist here both mechanically and chemically combined, as a resultant of the furnace action.

Aside from the elements which we have determined as being of commercial importance, there are doubtless many other substances which will present interest only from a scientific standpoint.

It is not unusual to find in these hangings both unconsumed coke and also charcoal.

Flue-dust will often completely cover these hangings at the top and under favorable conditions will become baked upon these hangings.

Cold walls primarily form or start these hangings, and as the ascending gases, whilst in a heated condition will follow the paths of least resistance, they will find this path to be along the furnace

walls. The products of combustion, whilst in a gaseous form, will mingle with the fumes of the metals and metalloids, and deposit, mainly upon the walls, sulphides of zinc and lead, and these two substances form the nucleus upon which many other substances become chemically and mechanically adherent.

The writer has from time to time observed a great many curious and interesting chemical compounds in connection with a study of these wall accretions; possibly the most interesting was the discovery of chloro-bromide of lead, which showed by analysis:

Pb—63.729%
Br—25.321%
Cl—10.345%

The formula Pb(Br Cl) requires Pb 64.186 and (Br+Cl) =35.814.

This interesting substance was described in 1881 in the *American Chemical Journal.*

Most beautiful iridescent and hopper-shaped crystals of sulphide of lead have been frequently observed in these hangings, and we have also noticed hollow tubes of chemically pure sulphide of zinc occurring in hollow pockets cut out in the hangings by means of the blast.

We have also found beautiful specimens, both of realgar and orpiment, in a highly crystalline state, in the main body of these hangings.

We have already described the different forms in which these hangings occur, their influence on the production of an increased amount of dust and fume, and many other interesting facts bearing upon these hangings in the *Engineering and Mining Journal*, February 6, 1886.

So far as tonnage of the furnaces is concerned these hangings often lessen the tonnage, and at other times they greatly increase the tonnage, but the amount of fume and dust is always greatly increased. It often becomes a very nice point to decide when to cut these hangings off, and how much to cut off, and how often the operation is to be performed.

It has been suggested that if one coated the inner brick walls with a good heavy coating of graphite that the hangings would not form so rapidly. The writer has tried this, and has to record a complete failure, and one can readily see that it would only be a very short time before the abrasion of the ore would wear off this

coating. Galena concentrates has a wonderful influence in causing the hangings to form rapidly.

Many years ago at Leadville, Colorado, it was observed in furnace charges containing practically no sulphide of lead that hangings of sulphide of lead would be formed rapidly. This was subsequently discovered to be due to too much sulphate of lead, which had been reduced to the sulphide.

It has been frequently suggested that it would be a good thing to carefully note the daily tonnage of a furnace, and when it had reached its maximum speed, to blow out the furnace and imitate the inner lines of the furnace for future construction. This may or may not be a valuable suggestion.

The writer has noticed that just as the size (the cubical contents) of the furnace has increased there was a tendency for the hangings to leave the side walls and to fill up at both ends; invariably will there be found more hangings in the back end of the furnace, that is to say, the end farthest away from the tap-hole.

It is very faulty construction to abstract the gases from the back end wall of the furnace. The good old-fashioned way of taking off the gases as nearly from the centre of the furnace is by all means the best. This statement we are lead to make after trying a great many different methods at different times. Finally, we state that the manner of feeding the charge into the furnace is the most potent factor bearing upon the formation of hangings. Whilst we think the ore, fluxes and fuel should be uniformly distributed over the entire top, yet the coarse pieces should be thrown as nearly into the center of the furnace as possible. The furnace drives faster, and there is not so much heated gases following the side walls, hence the tendency towards hangings is very much lessened.

HYDROGRAPHIC SURVEYS IN MONTANA.

By A. M. RYON, E. M.

THIS work has been in the past, and is at present, being carried on by the United States Geological Survey. The investigation includes the examination of reservoir sites and the feasibility of using such sites for increasing the available water supply; the examina-

tion of underground currents and artesian wells; the measurement of the flow of rivers and streams, and the preparation of reports upon the same.

The scope of this article will, however, be limited to a review of the work done and the methods employed in the measurement of the flow of rivers and streams in Montana.

To a great extent the value of stream measurements is apparent to any engineer, but it is doubtful if those unacquainted with the conditions existing in the arid West can fully appreciate the full importance of such information.

The value of such data for determining the available water for purposes of city or town supply, power, and for irrigation, is apparent at once; but, with the development of irrigation projects which in many communities have already taxed the water supply to the utmost, many new problems, not yet solved, have arisen. For example, streams flowing through several states are apt to be sources of contention, owing to the use of water in one state interfering with claims in another; trouble of this nature may even be of an international character. After irrigating, a portion of the water placed upon the land, which has not been used in contributing to plant-life, will eventually return to the river. A small portion returns as rainfall or snow, but past observations indicate that the increased precipitation due to the evaporation of water used for irrigating is insignificant. The amount which returns to the river by seepage from the fields, however, is undoubtedly large, probably in the vicinity of 30 % in many localities. The work of river flow measurement, carried on from year to year, will do much to aid the solution of these very important questions.

The importance of this matter may be further understood when it is remembered that the effect of this return seepage water is to steady the flow of the streams in much the same way that a forest does. In the arid West, where the majority of the streams have their sources in mountain torrents, this steadying effect is obviously desirable.

The measurement of flow in many instances will also furnish data concerning the effect of forest denudation. We may also learn much concerning the deposition of silt and the scouring effect of the different velocities under a variety of conditions.

It will be seen from the above considerations that the work of the Hydrographic Division of the United States Geological Survey

should receive encouragement from the public in general and engineers in particular. It may be of interest to understand the organization of this department and how the work is carried on.

The general supervision of the hydrographic work is carried on by "the Hydrographer," Mr. F. H. Newell, at Washington; Mr. Arthur P. Davis having general charge of stream measurements in the West and Mr. Cyrus C. Babb those of the Appalachian area. The immediate charge of the work in various districts is in the hands of parties who are paid merely for that part of their time which is actually devoted to the work.

These resident hydrographers are usually college professors or persons having a personal interest in work of this nature, but who have some regular outside employment insuring them a livelihood. The resident hydrographers establish gauging stations, take gaugings, employ observers, keep a record of all that pertains to their district and report to the hydrographer once a month. The observers notice the height of the river as shown on a gauge post. The readings are usually taken twice a day, and sent to the resident hydrographer once a week.

These observers, who are usually railroad section foremen or ranch men, receive a small compensation. The resident hydrographer, after copying the observer's gauge height readings, forwards them to Washington. At such times as the resident hydrographer deems it desirable, he gauges the streams at the various stations, using a current meter for the purpose.

Knowing the quantity of water passing a given station for different heights as indicated on the gauge, it is an easy matter to plot a curve, which will indicate the quantity of water passing for any intermediate points. From the curve thus drawn, a rating table is prepared, which shows at a glance the amount of water passing for any reading of the gauge. From this table, knowing the daily gauge heights, the daily flow is obtained.

This sounds very simple, but in a stream subjected to freshets, the bottom may be, and frequently is, constantly changing; sometimes scouring and sometimes being raised by the deposition of silt. It is obvious that in such cases a number of rating tables may be necessary to obtain a fairly accurate record of the daily flow for the year. Such a stream will, of course, require more frequent gaugings with the current meter.

The resident hydrographer, if familiar with the characteristics of

the stream, can usually tell by the reports showing the gauge heights, at what times it is advisable to take gaugings. If he is not familiar with the stream, it is necessary to have the observer send soundings occasionally, which would show if any change is taking place in the bottom.

To illustrate this point we may cite an experience of the writer: The West Gallatin River of Montana, showed an almost constant gauge height from August 1, '95, to November 29th, '95, yet the stream was constantly decreasing in volume, the flow decreasing from 1,160 cubic feet per second in August to 400 cubic feet per second in November. The bed of the stream in the meanwhile being gradually raised on an average, 0.86 feet.

The methods used in gauging the streams differ somewhat, depending upon the conditions found. The current meters used in Montana for this purpose were the Price meter and the Haskell meter. The former may be used in a very slow current and probably has an advantage over the latter in that the friction of the revolving wheel is reduced to a minimum, thus reducing the chances of error due to changes in the lubrication, from cold or other causes. The Haskell meter, on the other hand, is more compact and convenient to carry. An electric battery and a register are used in connection with these meters. The batteries are apt to be a nuisance, being as a rule cumbersome.

A small bi-sulphate of mercury battery of two hard rubber cells, placed compactly in a box about 2″ x 3″ x 4″, has lately been used by the survey, giving fairly satisfactory results.

The registers I have never found of any value as registers, but quite useful as sounders. It is far more convenient to count the clicks than it is to read the number of revolutions; for this reason ordinary telegraph sounders are frequently used.

The gaugings are taken from a bridge, where practicable; or from a boat, or from a box suspended from a wire rope stretched across the stream.

Where a wire rope is used, a barbed wire is stretched alongside the rope and tin tags are attached to the rope so as to mark the stations. The box is attached by ropes to pulleys running on the wire rope; its position being shifted along the rope by the occupant grasping the rope overhead and using main force.

A ten pound weight shaped something like a flat-iron is attached to the current meter, or if the current is too swift, another similar

weight is attached. A piece of sheet brass is fastened to the weights so that the wedge points up stream. The meter and weights are suspended by the insulated wire from the battery and register; but if two weights are used an additional cord is necessary. One reading is usually taken a few inches above the bottom, one near the surface, and if the depth is over four feet, or the current unusually swift, another in between.

The stations are usually placed ten feet apart along the bridge or wire rope; but this is a matter where judgment must be used.

Soundings are taken half way between the stations or more frequently if the depth of water changes abruptly. The entire cross-section of the river is in this way divided into sections, the current meter readings being taken in vertical lines through the middle of each section.

The average velocity shown by the two or three meter readings taken at each station, multiplied by the area of each section, gives us a close approximation to the amount of water passing at that

section. The sum of these quantities gives us a fairly close approximation to the actual discharge of the stream.

In taking meter readings it is convenient to count the revolutions for fifty seconds, as where two readings are taken at a station, we have simply to add them together and point off two places to obtain the number of revolutions per second. We may then obtain the velocity of the current directly from the meter rating table.

A simple method of keeping notes, very similar to the one adopted by the survey, is shown below:

Name of stream . . . . . Total flow . . . . . .
Location of station . . . . . Total area of
Name of observer . . . . . cross section . . .
Gauge height beginning. . . . . .
" " end . . . . . .
" " mean . . . . . .

Station.	Soundings.	Time.	Revolutions.	Rev. per second.	Average velocity.	Area of section sq. ft.	Flow cu. ft. per sec.	Remarks.
0								Temperature of water 50° F.; wind blowing briskly up stream. Conditions favorable for accurate results. b. stands for observation near the bottom. t. stands for observation near the top. NOTE: The number of the station shows its distance from the starting point.
5	2′	All observations 50″ each	b 30					
			t 30	.6	2.5′	20	50	
10	4′							
15	4′		b 40					
			t 40	.8	3.3′	40	132	
20	4′							

Near the gauging stations a 4″x4″ post is placed so as to be made as permanent as possible. The lower part of the post is often laid sloping for convenience. The divisions of feet and tenths are painted in black against a white back ground and were subjected to the continual action of ice or water. A row of tacks are used to prevent obliteration. The posts are used by the observer to asertain the daily height of water in a stream, and set, referred to two permanent bench marks.

It may be of general interest to know something of the discharge of the three streams, which, coming together at one point, from the head waters of the great Missouri River.

These streams vary greatly in their maximum discharge from year to year as well as from month to month. This will be under-

stood better when it is remembered that the freshets are caused by snow melting on the mountains in the spring season, a few hot days causing a rapid rise. Snow which has fallen during the early part of the winter and has become packed, melts more gradually than the loose snow recently fallen. So that the character of the winter weather also is a factor in the spring freshets.

The Madison River, having its source among springs in the Yellowstone Park, has a more constant flow than is usually found in mountain streams; its minimum flow during the year 1895 was about 1,400 second feet, its maximum flow about 3,900 second feet.

The Gallatin River had a minimum flow of about 528 second feet in 1895 and a maximum flow of 3,900.

The Jefferson River in 1895 had a minimum flow of about 1,000 second feet and a maximum flow of about 4,000; this was not determined in the field.

The freshet records of 1895 are chiefly valuable as indicating what may be expected during low water years.

Ordinarily the rivers are much higher than was the case during the spring of 1895; probably it would be safe to double the maximum flow as given for the Gallatin and Jefferson Rivers, to obtain an idea of the ordinary spring freshets.

THE SECOHMMETER AS USED IN THE ELECTRICAL ENGINEERING LABORATORY.

By W. H. FREEDMAN, C.E., E.E.

When a current in a circuit is increasing or diminishing, it exercises an inductive effect upon any neighboring circuit; this inductive effect being due to the change in the magnetic field surrounding the varying current. But since the magnetic lines surrounding a current may, as they move inwards or outwards from the wire, cut across other parts of the same circuit, it is evident that a current may act inductively on itself, producing an electromotive-force. This self-induced electromotive-force on turning the current on will tend to oppose the current, and prevent it growing as quickly as it otherwise would do, while that induced on stopping the current will tend to help the current to continue flowing. In

either case the effect of self-induction is to oppose change. The coefficient of self-induction or the induction of any circuit is equal to the number of volts of induced electromotive-force when the inducing current varies at the rate of one ampere per second. The unit of induction is called the Henry; so that a coil having an induction of three-tenths of a henry, means, that the current varying at the rate of one ampere per second would produce three-tenths of a volt counter-electromotive-force in that coil.

Messrs. Ayrton and Perry at one time proposed the name of Secohm for this unit, since, when determined by ordinary methods it is found to be the product of seconds by ohms. They also invented the secohmmeter, a device which, when employed in connection with a Wheatstone Bridge, is very useful in determining these inductive effects. The instrument consists fundamentally of two rotary commutators, each carrying four stationary brushes and both placed on the same shaft, thereby compelling synchronous rotation. One commutator is for periodically reversing the galvanometer connections, and the other for reversing the battery connections.

In order to make the apparatus more durable and at the same time decrease the difficulty of operation, it has been arranged in the following way:

Taking a one-sixth horse-power ten-ampere series motor, the two commutators of the secohmmeter are placed one at each end of the armature shaft. The commutator brushes are small cylinders of carbon bearing radially with quite a little pressure, in order to insure good contact and at the same time furnish a load for the motor so as to keep the speed within bounds. Care has been taken so that the brushes do not short circuit the battery, thereby enabling the use of a chloride storage battery for generating current.

The series motor is run from the 110 volt circuit through a parallel lamp bank. By screwing in or out lamps the speed can be varied at will. A revolution counter attached to one end of the shaft gives a simple means of accurately determining the speed whenever desirable.

To Compare two Coefficients of Self-Induction.

Connect up the apparatus as in Fig. 1. Arms r_1 and r_2 are non-inductive resistances while r_3 and r_4 are respectively composed of some non-inductive resistance in series with one of the coils whose coefficients are to be compared.

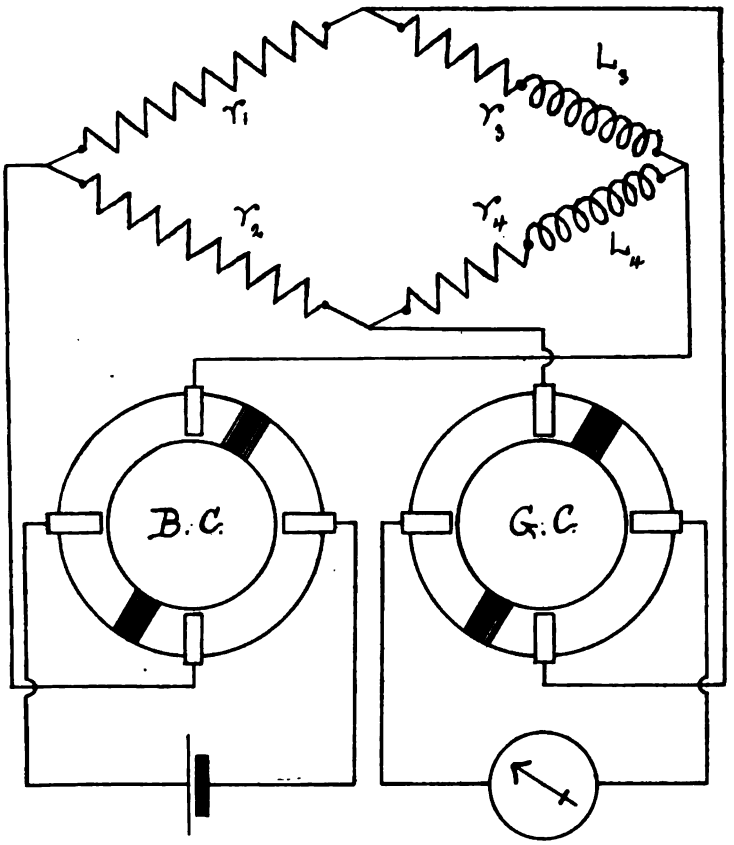

FIG. 1.

For simplicity suppose that the two commutators are replaced by two strap keys. First balancing the bridge in the usual way for steady currents, the arms are so arranged that

$$\frac{r_1}{r_2} = \frac{r_3}{r_4}.$$

Now the galvanometer-key is depressed before the battery key and unless the impedances of the inductive arms are in the ratio of r_1 to r_2 the galvanometer needle will throw. A balance can only be obtained for transient currents when

$$\frac{L_3}{L_4} = \frac{r_1}{r_2}$$

The equation may be demonstrated as follows: Let c_1 be the current through r_1 and c_2 that through r_2 at the same instant t after closing the circuit. Then since no current traverses the galvanometer when a balance has been obtained c_1 and c_2 are also the currents flowing through r_3 and r_4 respectively. At this instant our equations for the drop in the different arms must be

$$c_1 r_1 = c_2 r_2 \tag{1}$$

$$c_1 r_3 + L_3 \frac{dc_1}{dt} = c_2 r_4 + L_4 \frac{dc_2}{dt} \tag{2}$$

From Eq. (1) $$c_1 = c_2 \frac{r_2}{r_1}$$

Consequently substituting this in Eq. (2) it becomes

$$L_3 \frac{dc_1}{dt} = L_4 \frac{dc_2}{dt} \tag{3}$$

since the bridge is in balance for steady currents. Differentiating Eq. (1) with respect to t we obtain

$$\frac{dc_2}{dt} = \frac{r_1}{r_2} \frac{dc_1}{dt}$$

Therefore Eq. (3) becomes

$$\frac{L_3}{L_4} = \frac{r_1}{r_2} \tag{4}$$

In any method of measuring or comparing inductances which depend upon a bridge balance for transient currents, there is a certain lack of sensitiveness. In gaining a balance for steady currents a very small deflection of the needle may be multiplied and so made evident by properly closing and opening the galvanometer key. For transient currents, however, the direction of the throw of the needle differs upon closing and opening the battery key. In order that the multiplying effect may be obtained, it is necessary to reverse the galvanometer terminals between each closing and opening. The closing and opening of the battery circuit (or what is equivalent, the reversal of the battery) may be effected in synchronism with the reversals of the galvanometer by means of a secohmmeter.

Using a secohmmeter connected as in Fig. 1 we see, therefore,

that to keep the galvanometer at rest whether the commutators be rotated or not, we must have the coefficients of self-induction of the coils as well as the ohmic resistances in those arms in the ratio of $r_1 : r_2$.

The method of procedure adopted to fulfill both of these conditions is the following: Place $r_1 = r_2$; then adjust the non-inductive resistances in r_3 and r_4 until a balance is obtained for a steady current, *i. e.*, commutators stationary. Now rotate the commutators and note the direction and amount of the galvanometer deflection.

Then try r_1, say equal to $5r_2$. After obtaining a new static balance for this ratio, the rotate commutators again and note the deflection of the galvanometer. If the deflection is smaller, but in the same direction, then L_3 is greater than $5L_4$, but if the deflection has been reversed, then L_3 has a value between L_4 and $5L_4$. If the deflection is greater than before, then L_3 is less than L_4.

By continuing this method we can after a few more trials select such a ratio that the galvanometer will show no deflection whether the secohmmeter be rotated or not and we must have the coefficients of self-induction of the coils in the ratio $r_1 : r_2$.

The speed at which the commutators revolve need not be known, but the greater the speed the more sensitive the test; the rate of reversal must not, however, be too great for the currents to reach their steady values between two consecutive reversals.

In order to increase the sensitiveness of the bridge keep the ohmic resistances as small as possible. This gives more prominence to the inductive effects.

Measurement of a Coefficient of Self-Induction.

If in the preceding method giving us accurately the ratio between two unknown coefficients of self-induction, one of these coefficients as L_3 is a standard of self-induction, the equation gives the value of the other. Furthermore, if the standard is capable of having its inductance varied the obtaining of a balance is greatly facilitated. Such a standard is shown in Fig. 2. It contains two coils without iron, joined in series; one of them fixed and the other movable about a vertical axis. The inductance of the two depends upon their relative position. Calling the rotating coil A and the other B it is evident that the maximum inductance is ob-

tained when A coincides with B and the field due to its current reinforces that due to B. A smoothly graded variation of the inductance may then be gained by revolving the coil A until a mini-

FIG. 2.

mum value is reached, with A at 180° degrees from its preceding position. By means of a properly graduated circle over which a pointer attached to A moves, the value of the inductance may be read directly in henrys for any given position of A.

The employment of this standard greatly simplifies matters in determining the unknown L_4. First start with $r_1 = r_2$ and obtain a steady balance with the standard L_3 in its minimum position. Rotate commutators obtaining a deflection. Then place A in such a position till deflection is reduced to zero. If L_4 is greater than the maximum inductance of the standard it will be impossible to obtain a balance for transient currents. In this case r_2 must be made greater than r_1 and of such a value that first obtaining a static balance, the direction of the deflection corresponding to the minimum and maximum values of L_3 will be in opposite directions. Then the coil A is turned to the point at which the deflection is zero, when

$$L_4 = \frac{r_2}{r_1} L_3 \qquad (5)$$

ABSOLUTE DETERMINATION OF THE COEFFICIENT OF SELF-INDUCTION.

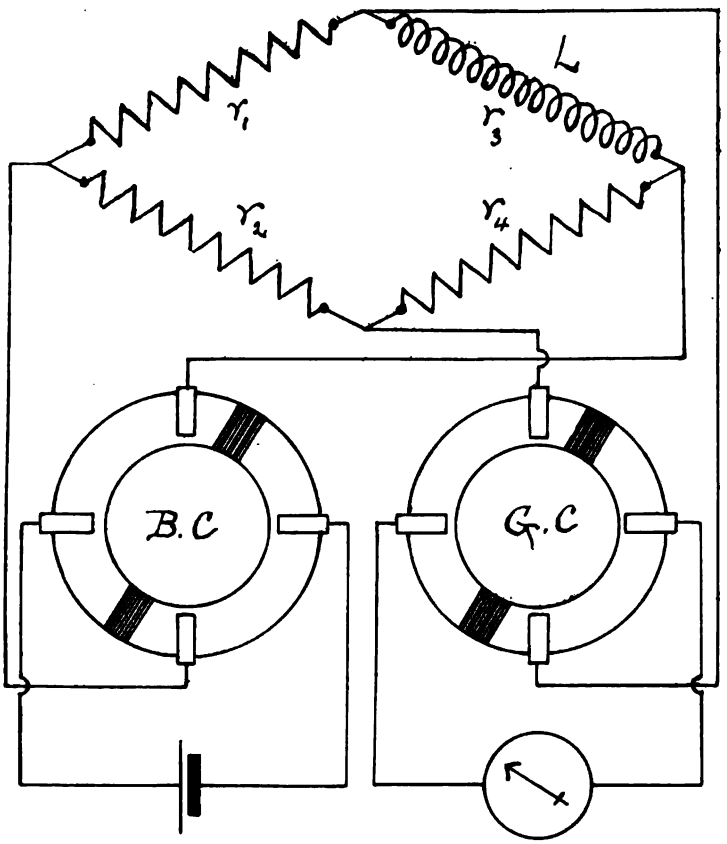

FIG. 3.

Connect up the apparatus as shown in Fig. 3. r_1, r_2 and r_4 are non-inductive resistances, while r_3 is the coil whose coefficient of self-induction L_3 is to be determined. First obtain a balance for steady currents by making

$$\frac{r_1}{r_2} = \frac{r_3}{r_4}$$

Rotate the commutators at some constant speed, n revolutions per second. This will cause the galvanometer to deflect, and this deflection can only be reduced to zero by changing one of the non-inductive resistances as r_4 a certain amount σ. Then

$$L = \frac{r_1}{r_2}\sigma\frac{k}{n} \tag{6}$$

where k is a constant depending upon the relative position of the commutators and the form of the current waves in the bridge arms.

For let c_1 and c_2 be the values of the currents in arms r_1 and r_2 at some time t after the circuit has been closed. Then if there is a balance for transient currents there will be no current through the galvanometer and c_1 and c_2 will also be the currents in r_3 and r_4 respectively. At this instant our equations for drop in the various arms must be

$$c_1 r_1 = c_2 r_2 \tag{7}$$

$$c_1 r_3 + L\frac{dc_1}{dt} = c_2 r_4 + c_2\sigma. \tag{8}$$

Dividing Eq. (8) by Eq. (7)

$$\frac{r_3}{r_1} + \frac{L}{c_1 r_1}\frac{dc_1}{dt} = \frac{r_4}{r_2} + \frac{\sigma}{r_2}$$

which gives

$$L\frac{dc_1}{dt} = \frac{r_1}{r_2}\sigma c_1. \tag{9}$$

because of $\frac{r_3}{r_1}$ being equal to $\frac{r_4}{r_2}$.

Suppose now that we call C_1 the maximum value of c_1 and Q_1 the total number of coulombs that pass through the coil L_3 from the time $c_1 = 0$ until $c_1 = C_1$. Evidently then at any moment, $c_1 = \frac{dQ_1}{dt}$.

Equation (9) may therefore be written

$$L\frac{dc_1}{dt} = \frac{r_1}{r_2}\sigma\frac{dQ_1}{dt} \tag{10}$$

If equation (10) is true the definite integral of both members must be true. Therefore

$$L\int_0^t \frac{dc_1}{dt}\,dt = \frac{r_1}{r_2}\sigma\int_0 \frac{dQ_1}{dt}\,dt \tag{11}$$

If the upper limit to be taken so that the current has reached its maximum value equation (11) becomes

$$LC_1 = \frac{r_1}{r_2}\sigma Q_1 \tag{12}$$

In this same length of time t, if instead of having the current varying, a constant current C_1', equal to the mean value of c_1 had

flowed, then the same number of coulombs Q_1 would have been transferred or,

$$Q_1 = C_1' t.$$

Furthermore, C_1' will be approximately a constant percentage of C_1. Now if the commutators revolve at n revolutions per second then $t = \frac{1}{2n}$ and Eq. 12 can therefore be written

$$L = \frac{r_1}{r_2} \sigma \times \frac{1}{2n} \times \frac{C_1'}{C_1},$$

or

$$L = \frac{r_1}{r_2} \sigma \frac{k}{n}. \qquad (13)$$

COMPARISON OF CAPACITIES.

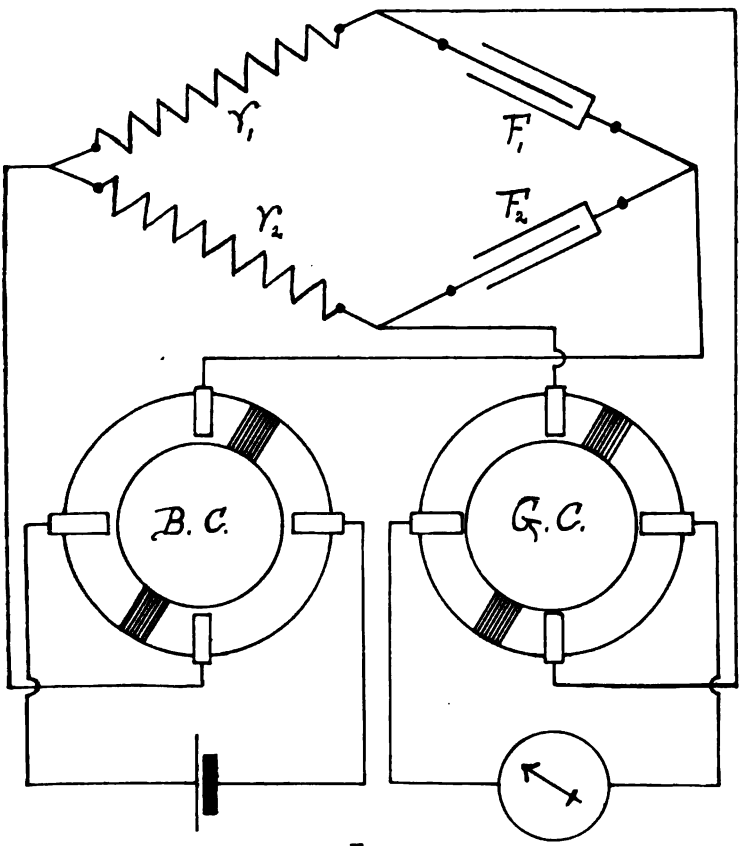

FIG. 4.

By arranging the connections as shown in Fig. 4 two capacities can be compared.

r_1 and r_2 are non-inductive resistances, while F_1 and F_2 are the capacities. Rotate the secohmmeter and then adjust r_1 and r_2 until there is zero galvanometer deflection, when

$$\frac{F_1}{F_2} = \frac{r_2}{r_1} \tag{14}$$

It is to be noticed here that the capacities will be inversely as the ratio of the resistances *i. e.*, the greater capacity will be in series with the smaller resistance.

When a balance has been obtained the equation of drop must be

$$C_1 r_1 = C_2 r_2 \tag{15}$$

where C_1 and C_2 are the currents flowing in r_1 and r_2 at any instant t after closing the circuit.

If Q_1 is the final charge in F_1 and Q_2 that in F_2 Eq. (15) may be written

$$r_1 \frac{dQ_1}{dt} = r_2 \frac{dQ_2}{dt}$$

Integrated between the times, zero and that when the condensers are fully charged we have,

$$r_1 \int_0^t \frac{dQ_1}{dt}\, dt = r_2 \int_0^t \frac{dQ_2}{dt}\, dt$$

$$r_1 Q_1 = r_2 Q_2 \tag{16}$$

When the condensers are fully charged we will have

$$Q_1 = E F_1 \tag{17}$$

$$Q_2 = E F_2 \tag{18}$$

where E is the electromotive-force of the battery.

Combining Eqs. (17) and (18) with (16)

$$r_1 F_1 = r_2 F_2$$

or

$$\frac{F_1}{F_2} = \frac{r_2}{r_1}$$

As in case of comparison of inductances, increasing the speed at which the sechommeter is driven merely increases the sensibility of the test without affecting the ratio connecting the capacities with the resistances.

For further uses of the secohmmeter the student is referred to *Electrical World*, Vol. XIII., p. 232; Jackson's *Alternating Currents*, Vol. II.; Gray's *Absolute Measurements in Electricity and Magnetism*, Vol. II.; Carhart & Patterson's *Electrical Measurements;* Munro & Jamieson's *Pocket Book.*

ABSTRACTS.

ANALYTICAL CHEMISTRY.

By ELWYN WALLER, PH.D.

Spectrographic Analysis. Hartley. (Proc. Lond. Chem. Soc. 1896. 98.) In order to determine the composition of a coin without destroying it the spark spectrum was obtained and photographed. Then trial alloy, were made and the spark spectrum of these obtained. The alloy yielding an identical spark spectrum was then analyzed.

Converting Sulphates to Chlorides. Jannasch. (Zts. Anorg. Chem. XII. 223.) Pulverize the dry salts, mix with four to five times their weight of anhydrous B_2O_8 and fuse until SO_8 fumes cease to be evolved. Then boil with a considerable excess of HCl, adding methyl alcohol with HCl two or three times to volatilize off the B_2O_8.

Glass, attacked by "Magnesia Mixture." De Konnick. (Chem. Ztg. XX. 129.) In a flask of Jena glass in thirteen months the loss amounted to 1.5 mgms. per square cm. Magnesium silicate was formed. With Stas's glass, the loss was under 1 mgm. Ostwald's method of treating the glass apparatus with steam before using, appeared to render the glass much less susceptible to attack.

Ammonium Citrate in Fertilizer Analyses. Determination of neutrality. Lord. (J. Am. Chem. Soc. XVIII. 457.) Add some litmus solution (prepared according to Sutton), to 100 cc. of water. Divide in halves, and place in two Nessler tubes. Add to one a drop of H_2SO_4, to another a drop of NH_4OH. Arrange the tubes, one in front of the other, so that on looking across them the colors are superposed. To another Nessler tube add 5 cc. of the citrate solution, litmus solution to correspond to that in the first pair, and water to bring the volume up to 50 cc. When the colors correspond, the citrate solution is neutral.

Lime and Sulphuric Acid. "Photometric Method." Hinds. (Chem. News. LXXIII. 285.) By precipitating in a cylinder such as a Nessler tube, and measuring the depth of liquid containing suspended precipitate which just sufficed to obscure a candle flame placed about a foot below the bottom of the tube, surprisingly close results were obtained.

The product of the multiplication of the depth of liquid into per cent. of SO_3 was found to be a constant, which when once obtained for any given tube will serve for calculations.

Standardizing Permanganate and Sulphuric Acid. Morse and Chambers. (Am. Chem. Jour. XVIII. 236.) The reaction with H_2O_2 is: $2KMnO_4 + 5H_2O_2 + 3H_2SO_4 = K_2SO_4 + 2MnSO_4 + 8H_2O + 5O_2$. It was found that this reaction occurs sharply, so that when a perfectly neutral solution of H_2O_2 was used, any excess of $K_2Mn_2O_8$ or of H_2SO_4 (according to which one was being tested) could be made manifest. The H_2O_2 solution was made neutral by agitation with ZnO and filtering through asbestos.

Ammonia free water for Nesslerizing. Barnes. (J. S. C. I. XV. 254.) One or two litres of ordinary distilled water are placed in a stoppered bottle, and a little Br vapor is then poured into it. After shaking the

water should be just perceptibly tinted, and should give a blue coloration when dropped on iodide and starch paper. One drop of a strong solution of NaOH is now added, and the bottle shaken and placed aside for ten minutes. Finally one or two drops of a solution of KI are added, and the water will then be found to be free from NH_3 and suitable for Nesslerizing purposes.

Ammonium Sulphide Group. Qualitative Tests. Tarugi. (Gazetta. XXV. 478.) Ammonium ferricyanide is proposed as a substitute for $(NH_4)_2S$. After separating Fe.Al, etc., by NH_4OH and NH_4Cl—the solution is boiled, slightly acidified with HCl, and after adding a slight excess of $(NH_4)_6Fe_2Cy_{12}$ it is warmed and filtered. CO, Ni and Mn, are precipitated. From the filtrate Ba, Sr and Ca are separated as usual by $(NH_4)_2CO_3$. Mg by $(NH_4)_2HPO_4$, and in the filtrate from that acidification with acetic, will precipitate $Zn_3\ Fe_2\ Cy_{12}$ if Zn is present. The precipitate of mixed ferricyanides is treated with cold NH_4OH which extracts Ni, (shown on acidification of the filtrate). In the residue Mn may be detected by fusing with KNO_3 and Na_2CO_3 or by PbO_2, etc. Co by the bead test or by igniting. dissolving and applying the KNO_2 test.

Iron and Alumina in Phosphate Rock. Gladding. (J. Am. Chem. Soc. XVIII. 717 and 721.) The acetate method is accurate if three precipitations are made in presence of an excess of phosphate. Remove any metallic iron, resulting from pulverization in iron mortar by means of a magnet. Digest 4 gms. for 30 minutes with 30 cc. of dilute HCl (1 : 1) at just below boiling. Filter, and wash into a 200 cc. flask, add HNO_3 and boil to oxidize Fe, cool, and fill to the mark with water. Take two portions of 50 cc. and 25 cc., nearly neutralize each with strong ammonia. finishing the neutralization with weak ammonia. Redissolve the precipitate with as little HCl as possible. Pour the cold mixture, with stirring, into 15 cc. $NH_4C_2H_2O_2$ (strong solution) with 5 cc. $HC_2H_3O_2$. Digest at 60° C for 30 to 60 minutes until the precipitate settles well. Filter, wash once with 10% $NH_4C_2H_3O_2$, dissolve in a little dilute HCl back into the original beaker, add 1 gm $(NH_4)_2HPO_4$, neutralize and precipitate as in the first case. Repeat re-solution and re-precipitation again. Wash with dilute $NH_4C_2H_3O_2$. Ignite slowly, finally using the blast lamp for half a minute. Cool and weigh $Al_2(PO_4)_2$ with $Fe_2(PO_4)_2$. Fe is determined volumetrically in another portion. The method is somewhat tedious. A more rapid method is described, similar to that of Lasne (vid QUARTERLY XVII. 312). The method was devised and has been used by the author for a year before the appearance of Mr. Lasne's paper.

Aluminum Analysis. Handy. (J. Am. Chem. Soc. XVIII. 766.)

As solvents may be used: HCl diluted with water (1 : 2).

"Acid mixture," consisting of 100 cc. of HNO_3 (Gr. 1.42), 300 cc. HCl (Gr. 1.2) and 600 cc. of 25% H_2SO_4.

NaOH solution of 33%. 15 cc. will dissolve 1 gm. Al.

One also requires standard $K_2Mn_2O_8$ (5.76 gms. in 2 litres), 1 cc. = 0.005 Fe, standard KCy (45 gms. in 2 litres) 1 cc. = about 0.005 Cu. Also powdered Zn, free from Fe and Cu.

For ordinary commercial aluminum proceed as follows: In a 4½ inch evaporating dish dissolve 1 gm. of the Al drillings in 30 cc. of "acid mixture." Do not add all the acid at once if the action is vigorous. Complete the solution by warming and then boil down quickly to strong

SO_3 fumes. Attention is necessary for the regulation of the heat when $Al_2(SO_4)_3$ begins to crystallize out. Keep up the heat for 5 minutes while SO_3 fumes are strongly evolved. Allow to cool a little, and add 75 to 100 cc. H_2O and 10 cc. of 25% H_2SO_4, break up the residue with a stout glass rod, and boil to dissolve $Al_2(SO_4)_3$. Add approximately 1 gm. of the powdered Zn, pouring it *into the middle* of the liquid. Keep the dish at 60 to 70° C. until the Zn has dissolved, leaving Fe reduced and Cu precipitated. Filter and titrate filtrate with standard $K_2Mn_2O_8$. Change the receiver, and dissolve the Cu through the filter by use of two lots of hot 15% HNO_3 (by vol.). Wash out with water, and in the solution determine Cu by adding saturated Na_2CO_3 solution in excess, until re-solution of precipitated $CuCO_3$ in the $NaHCO_3$ which is formed, and then titrate with standard KCy.

The SiO_2, etc., from which the Cu was dissolved off, is fused with 1 gm. Na_2CO_3. Dissolve the mass out with 15 cc. of water in the dish in which solution was first effected, and then add 25 cc. of 25% H_2SO_4. After rinsing out the crucible, evaporate to 5 minutes fuming on the hot plate, cool and boil with about 100 cc. of water. Filter, wash, etc., weigh SiO_2, etc. Expel SiO_2 by HF and H_2SO_4, ignite and weigh. Loss is SiO_2. This is the ordinary examination for grading the aluminum.

Graphitic Silicon. Dissolve 1 gm. in dilute HCl (1 :2) in a platinum dish—add about 2 cc. of HF, stir, and filter immediately through a 9 cm. paper, in a funnel lightly coated with paraffine, wash with water, then fuse the paper and contents with 1 gm. Na_2CO_3 and continue in the same manner as described for total Si above.

Sodium. Dissolve 1 gm in 50 cc. HNO_3 (Gr. 1.3) with the aid of what HCl may be necessary, rinse into a large platinum disk, and evaporate to dryness heating over a burner until no more nitrous fumes are evolved. Grind the residue finely and treat by J. Lawrence Smith's method for alkalies in minerals. (Fusion with 1 gm. NH_4Cl and 8 gms. $CaCO_3$ etc.), weigh NaCl obtained, proving its purity carefully: 0.2% of Na is regarded as high.

Carbon. The method is a modification of Moissan's (vid QUARTERLY XVII. 312.) Trituration of the drillings with $HgCl_2$ and water. Dry and volatilize off Hg and its compounds by heating in a current of H. Then burn to CO_2 as in C determinations in iron and steel.

Aluminum. Dissolve 1 gm. in 30 cc. of HCl (1 :2) and evaporate to complete dryness, redissolve in 10 cc. HCl with 75 cc. water, rinse into a No. 3 beaker, dilute to about 250 cc.—saturate with H_2S, filter and then boil out H_2S, add 1 cc. HNO_3 and boil 10 minutes to oxidize, cool and make up to 500 cc., take out 50 cc., precipitate with NH_4OH and boil 20 minutes, wash thoroughly. It is necessary to wash the precipitate off from the filter, break it up and wash it back again, ignite intensely and weigh quickly. Al_2O_3 is completely dehydrated with difficulty and when dehydrated reabsorbs moisture very rapidly.

Aluminum Alloys. An alloy containing no Zn or Ni can be dissolved in 33% NaOH, the Cu etc., filtered off and after thorough washing the Cu is dissolved through the filter by HNO_3, and titrated with standard KCy.

Ni. Alloys. A 3% alloy is now used. Dissolve 1 gm. in 15 cc. NaOH as above. Dilute, filter and wash, then rinse off the Ni and Cu by 3 to 5 cc.

conc. HNO_3 with a drop of HCl. Boil until dissolved, cool and make up to 250 cc. Take 100 cc., neutralize, add 2 cc. HCl, precipitate out Cu by H_2S, filter that off and determine as above with KCy, oxidize the filtrate by boiling with 1 cc. HNO_3, precipitate with NH_2OH. Keeping the solution for a few minutes at just below boiling, filter, redissolve in dilute HNO_3 and reprecipitate; weigh Fe_2O_3, etc. In another 100 cc. precipitate CuO, NiO and Fe_2O_3 by NaOH, wash, etc., and weigh; deduct CuO and Fe_2O_3 and get NiO by difference.

Mn. Alloy. Dissolve 1 gm. in HCl, evaporate down with HNO_3, precipitate Mn by $KClO_3$; determine by Williams' method.

Cr. Alloy. Dissolve 1 gm. in dilute HCl, add 50 cc. conc. H_2SO_4 and evaporate to fumes, dilute and boil—add powdered $K_2Mn_2O_8$ until the solution retains a pink color, boil until this excess is decomposed, filter through washed asbestos and determine Cr by Galbraith's method.

W. Alloy. The plan pursued is essentially the same as that for Si. Solution in HCl, evaporation to dryness, fusion of the insoluble residue with Na_2CO_3, dissolving and again evaporating to dryness to separate SiO_2 and WO_3, finally expelling SiO by HF, etc., and weighing WO_3.

Ti. Alloy. Dissolve 2 gms. in 50 cc. of 10% KOH. Dilute to 125 cc. boil up and filter quickly. Wash ten times with boiling water. Burn paper in porcelain crucible, crush in a mortar and fuse in platinum with 10 gms. $KHSO_4$—10 minutes at a low heat (lower portion of crucible red hot) and 5 minutes at high heat (flames enveloping the crucible) then 10 minutes at low heat again. Cool, dissolve in 200 cc. water. Filter—if insoluble portion is not all volatilized by treatment with HF and H_2SO_4, fuse again to recover TiO_2. Make first alkaline with NH_4OH, then acid with H_2SO_4, dilute to 300 cc. Reduce with SO_2 and boil for an hour, adding SO_2 water occasionally. Filter, etc., weigh TiO_2.

Zn. Alloy. Dissolve in 30 cc., dilute HCl, dilute to 200 cc. and separate Cu by H_2S at boiling heat. Filter, oxidize by 1 cc. HNO_3 and boiling, neutralize closely with NaOH, add 10 gms. $NaC_2H_3O_2$ and 500 cc. water, boil—redissolve precipitate and repeat basic acetate separation. Precipitate Zn from filtrate by H_2S, ignite to ZnO and weigh.

Directions are also given for the analysis of solders, hydrated and calcined alumina, Bauxite, etc.

Chromium Hydroxide in Precipitation. Patten. (Am. Chem. Jour. XVIII. 608.) Experiments indicated that $Cr_2(OH)_6$ precipitated in presence of sulphates, retained some SO_3 in chemical union, not simply in "molecular adhesion" as is usually asserted. The base of the sulphate (K_2O or MgO) was not retained by the precipitate.

Chromium in Steel. Stead. (Jour. Iron and Steel Inst.) Modification of Galbraith's process. Dissolve in dilute H_2SO_4 fuse the residue with $KNaCO_3$ dissolve, acidify with HCl and titrate with standard $FeSO_4$ and $K_2Cr_2O_7$ solutions. To the H_2SO_4 solution (300 cc.) strong $K_2Mn_2O_8$ is added until the red color persists (hot) for 10 minutes; then 80 cc. HCl is added and it is heated until the excess of $K_2Mn_2O_8$ is destroyed. 150 cc. of water is added, about 100 cc. boiled off to expel Cl, and the solution titrated with $FeSO_4$ etc., as before.

Another method consists in dissolving in HCl, treating with Na_2O_2 and precipitating by use of Na_2HPO_4 and $Na_2S_2O_3$ then fusing the $Cr_2(PO_4)_2$ so as to obtain alkaline chromate acidifying and titrating as above.

Chrome Ore and Ferrochromium. Sandifer. (J. S. C. I. XV. 155.) For chrome ores. Fuse 0.5 gm. of the moderately finely ground ore in a nickel capsule with 3 gms. Na_2O_2, holding the capsule by the tongs in a flame, giving the contents a circular motion. The temperature should be just short of visible red. Three minutes suffice for complete decomposition. Cool, dissolve out with cold water, in a porcelain basin, pour the solution into a beaker, rinse out with hot water, dilute to about 300 cc. with hot water, make pink with $K_2Mn_2O_8$, then add gradually 100 cc of dilute HCl, boil until clear, add 150 cc. of hot water and boil again for 10 minutes to remove Cl—cool, and titrate with $FeSO_4$ and $K_2Cr_2O_7$ (standard solutions).

For Ferrochrome. Crush in a steel mortar until the powder will pass a 100 mesh sieve, mix 0.3 to 0.5 gm. of the sample with 4 gms. Na_2O_2 and 0.75 gm. BaO_2 in a nickel capsule, the rest of the process is conducted as for ores, except that a larger excess of $K_2Mn_2O_8$ is added.

The author takes issue with Rideal and Rosenblum (vid QUARTERLY XVII. 313.) as to the presence of Na_2O_2 in the solution after the fusion, and also as to the necessity for fine grinding of ores to insure complete decomposition.

Rapid Determination of Manganese in Ores. (Särnström-Swedish Method.) Mixter and Dubois. (J. Am. Chem. Soc. XVIII. 385.) Treat 0.5 grm. of the ore in a No. 0 beaker with 15 cc. HCl (Gr. 1.1), boiling until the residue is clear. If necessary, fuse up the residue with Na_2CO_3, dissolve in HCl and combine the solutions. Add a few drops HNO_3 to insure oxidation of FeO and C, and heat for a short time to expel lower N oxides. Rinse into a No. 3 breaker or a flask, fill the same about two-thirds with boiling water, and add solid Na_2CO_3 or $NaHCO_3$ in quantity just sufficient to precipitate all Fe. Use a solution of carbonate at the end to avoid having an excess. Under these conditions, the Mn is retained in the solution in virtue of the presence of the CO_2, and can be titrated by the Volhard method, the temperature being kept at about 80° C. Filtering off the $Fe_2(OH)_6$ should not be done. Where the percentages of Mn are high (30 to 50), the results are low as compared with gravimetric, but for 0.1 to 8% Mn, they compare satisfactorily.

Volhard's Method for Manganese. Stone. (J. Am. Chem. Soc. XVIII. 228.) Dissolve an amount of material containing 0.05 to 0.15 grm. Mn in small excess of acid. HNO_3, HCl or H_2SO_4 may be used as the solvent, without interfering with the results provided the iron is oxidized before precipitation and titration. Alloys may be dissolved in HNO_3 (of Sp. Gr. 1.10), ores in HCl with a little $KClO_3$. Cool—rinse into a 500 cc. flask and add emulsion of ZnO until the precipitate curdles, dilute to the mark, mix well and pour into a beaker. When it has settled decant off 100 cc.—dilute to about 200 cc., heat to boiling in a porcelain casserole, and titrate with $K_2Mn_2O_8$ of which 1 cc. = 0.001 grm. Mn (about 199 gms. $K_2Mn_2O_8$ per litre), stirring vigorously all the time.

Manganese in Steel. Volhard Method. Auchy. (J. Am. Chem. Soc. XVIII. 498.) The sources of error in the method as described by Volhard are: 1. Incomplete neutralization by ZnO, giving high results. 2. Too *sudden* addition of excess of ZnO giving low results. 3. Titration in HNO_3 solution giving high results (by 0.01 to 0.02%). 4. Neutralizing by ZnO in *hot* solution giving high results. Special treat-

ment to oxidize the carbonaceous matter was not found by Stone to be necessary. The author confirms this view. The method recommended is in brief: Dissolve 3.3 gms. in 50 cc. HNO_3 (Gr. 1.2). Wash into 500 cc. flask. Neutralize about two-thirds by Na_2CO_3 (sal soda) solution. *Cool*, add emulsion of ZnO until the solution stiffens, *avoiding excess.* Dilute to about 375 cc., mix and let stand until $Fe_2(OH)_6$ begins to settle. Then *add considerable excess* of ZnO emulsion. Mix, dilute to mark, stopper, mix, transfer to dry beaker, mix, let settle, pour off 250 cc. Titrate in a 500 cc. Erlenmeyer flask, after heating to boiling. Correct for impurities in ZnO and Na_2CO_3. Calculate, *Deduct 0.02%.*

Cobalt in Presence of Nickel. Qualitative. Durrant. (Proc. Lond. Chem. Soc. 1896.) Addition of excess of $NaHCO_3$ (or $KHCO_3$) solution to a Co solution, followed by H_2O_2 affords a green liquid. Possibly H_2CoO_4. The maximum intensity of coloration seems to appear when molecular proportions of Co and H_2O_2 are as 1: 2. The probable reaction is: $CoCO_3 + 2\,H_2O_2 = H_2CoO_4 + CO_2 + H_2O$.

Copper Sulphide. Brauner. (Chem. News. LXXIV. 99.) The author has found that the precipitate produced by H_2S in Cu solutions is never CuS alone, but consists of CuS with Cu_2S combined apparently in different proportions according to the conditions produced, together with some free S.

The mode of examination consisted in placing an unweighed quantity of the precipitate in a flask, adding water and some $KClO_3$, then inserting a small test tube containing fuming HNO_3. After stoppering the flask and tying the stopper down, the HNO_3 was tipped out little by little. When all action in the cold had ceased, the stopper was removed and the oxidation completed with application of heat. The solution was divided in halves, one-half being used for the S determination, the other for Cu.

Separation of Copper. Mawrow and Muthmann. (Zts. Anorg. Chem. XI. 269.) The reagent recommended is hypo-phosphorus acid (H_3PO_2). The solution had best be that of sulphates. HCl is inadmissible, the nitrate and acetate consume much of the reagent or are slow. The solution should be diluted until 100 to 200 cc. contains 0.1 gm. Cu, when the reagent is added and heat is applied until there is no more evolution of gas, and the metal has coagulated. It can then be filtered off, and if a quantitative determination is needed, washed with water, then with alcohol, etc. The reaction affords a rapid and complete separation from Cd or Zn.

Cyanide Process for Copper. Denigés. (Bull. Soc. Pharm. Bordeaux. 1896. 18.) Keeping the solution *boiling* throughout the titration afforded constant results, independent, apparently, of the proportions of NH_3 or of NH_4 salts present.

Volumetric for Copper. Spica. (Staz. Sper. Agrar. XXVI. 593.). Titration is performed with a solution of ferrocyanide 8.4569 gms. crystals per litre (1 cc. = 0.0025 gm. Cu). The end reaction is obtained by "spot" tests on a paper which has been wetted with Fe_2Cl_6. Ni does not interfere unless much is present. Any errors of the kind, however, may be obviated by separating out the metal as CuS, filtering and dissolving in HNO_3 for titration.

Volumetric for Copper. Rupeau. (Bull. Soc. Pharm. de Bordeaux, Oct. 1895.) Ammonium picrate gives a precipitate of Cu, insoluble in ammonia. Dissolve 7.5 gms. picric acid in hot water, add 30 to 40 cc.

of ammonia or until a decided odor is perceptible and then make up to 1 litre. Let stand, filter, and then standardize by use of a solution of 1 gm. of pure Cu, dissolved in HNO_3 and made up to 100 cc. Run in the picrate solution with stirring, until the supernatant solution shows clear yellow without any shade of green. If Ag is present, add ammonia to the solution containing the Cu. Fe can be precipitated out by ammonia before proceeding to titrate. Any interference caused by Pb, can be obviated by adding a little tartaric acid.

Copper by the Iodide Method. Low. (J. Am. Chem. Soc. XVIII. 458.) Instead of neutralizing the HNO_3 solution with Na_2CO_3 and acidifying with acetic, an excess (6 or 7 gms.) of Zn $(C_2H_3O_2)_2$ is added before adding KI (3 gms.). The $Na_2S_2O_3$ solution is made up with 19 gms. of crystals per litre 1 cc. = about 0.005 gm. Cu.

For ores it is recommended to decompose with HNO_3 followed by HCl, then to evaporate with H_2SO_4, filter off $PbSO_4$ and gangue, and from the solution to precipitate out the Cu by metallic Al, dissolve this in HNO_3, and proceeding with the usual precautions—(boiling out lower oxides of N etc.). If As is present, it must be oxidized to H_3AsO_4 by previous boiling with a little $KClO_3$. In that form it does not interfere.

Oxygen in Commercial Copper. Blount. (Analyst. XXI. 57.) The $AgNO_3$ method which is usually used gives fallacious results, the indications of the process disappearing when the errors are eliminated. The only process tried, which appeared to give accurate results consisted in melting the Cu in a current of H, and weighing the water formed. The H (generated by H_2SO_4), is passed through $CuSO_4$ solution then through a drying tube, containing conc. H_2SO_4 then through a bulb tube of platinized asbestos heated to red heat to remove O from the Zn, then through conc. H_2SO_4 drier, then over the molten Cu. The latter is weighed out (10 to 15 gms.) in a porcelain boat which is inserted in a porcelain combustion tube, set in a small injector furnace. The connection tube to the porcelain is a T-tube one arm of which is sealed, which permits the observation of the progress of the operation. The water formed is caught in weighed tubes containing H_2SO_4 and pumice.

Bismuth Sulphide. Stillman. (J. Am. Chem. Soc. XVIII. 681.) It is found that Bi_2S_3 is perceptibly soluble in Na_2S solution. In cases of analyses of "magnolia metal" and similar alloys, Bi might entirely escape determination, if Na_2S were used to separate the metallic sulphides.

Mercury by Sodium Peroxide. Schuyten. (Chem. Ztg. XX. 239.) Na_2O_2 when warmed in solution with Hg salts affords metallic Hg. The plan recommended is to place the solution of the salt in a porcelain dish which may be covered with a funnel having the stem turned at right angles. Na_2O_2 is added little by little to the contents of the dish, until no further precipitation occurs, when it is covered with the funnel, and gently warmed until steam condenses in the tube. After cooling, the funnel is well washed—the Hg filtered off—dried in the dark and weighed. The halogen present may be determined in the solution by Volhard's method.

Volumetric for Lead. Pope. (J. Am. Chem. Soc. XVIII. 737.) The method consists in converting the Pb to $PbSO_4$ then to acetate—adding an excess of standard $K_2Cr_2O_7$, destroying that excess with

standard As_2O_3 solution and titrating the excess with standard I solution by $Na_2S_2O_3$ and starch indicator.

Alloys of Lead, Tin, Antimony and Copper. Thompson. (J. S. C. I. XVII. 179.) Preliminary Qualitative tests: For Pb: Dissolve in aqua regia. If $PbCl_2$ does not separate on cooling, test further by adding 4 vols. alcohol, which will give a precipitation of $PbCl_2$ if 0.5% or more of Pb is present.

For Sn: Dissolve in HCl and KCl. Before the metal has completely dissolved, decant the solution, cool, and add alcohol as above to separate $PbCl_2$, oxidize to $SnCl_4$ by Br water, boil out Br, dilute, and pass H_2S to get SnS_2 with its characteristic color.

For Sb: Treat with conc. HCl. Almost all Sb is left. Decant, wash the residue well, and then dissolve it in HCl and $KClO_3$, boil out free Cl, and then pass H_2S. If Cu is present, the color of the Sb precipitate may be obscured by the black of the CuS. Extract Sb_2S_5 with KOH, in which solution (orange) Sb_2S_5 may be precipitated by acidifying.

For Cu: Dissolve in HNO_3 and evaporate in porcelain dish. When nearly dry the salts crystallizing out at the edge of the residue will show the green of Cu salts.

For As: Dissolve in an Erlenmeyer flask with HCl and $KClO_3$, boil out free Cl, add HCl and 2 gms. $Na_2S_2O_3$, connect with condenser and distil. Test the distillate with H_2S for As (yellow As_2S_3).

For Quantitative analysis, dissolve in a solution made as follows: 20 gms. KCl in 500 cc. H_2O, add 400 cc. conc. HCl, mix, and then add in the cold, 100 cc. HNO_3 (Gr. 1.4). Boil 1 gm. of the alloy with 70 to 100 cc. of this solution, adding more of the solvent, if it should be found necessary. Boil down to about 50 cc. Cool to separate $PbCl_2$ and add gradually 100 cc. of 95% alcohol. Let stand 20 minutes, filter, wash with alcohol and HCl (4 to 1). Redissolve the $PbCl_2$ back into the original beaker with boiling water, finally with NH_4A add 15 cc. saturated solution of $K_2Cr_2O_7$, heat, filter through a weighed Gooch crucible, wash with water, alcohol and ether, dry at 100° C. and weigh $PbCrO_4$.

Evaporate the filtrate from the $PbCl_2$ to dryness, add 10 cc. KOH (1 in 5) and after a few minutes 20 cc. of a 3% solution of H_2O_2. Heat on the water bath for 20 minutes, add 10 gms. $(NH_4)_2C_2O_4$ 10 gms. $H_2C_2O_4$ and 200 cc. of water. Heat to boiling, pass H_2S for 45 minutes at that temperature, filter at once and wash the $Sb_2S_3 \pm CuS$ with hot water. Boil out H_2S, concentrate if necessary, and electrolyze over night with a current of about ½ amp. By morning the solution is usually alkaline, indicating that probably all Sn has been precipitated on the cathode as SnO_2, wash with water, then with alcohol, dry and weigh SnO_2.

Treat the Sb_2S_3 and CuS, with 10 cc. KOH solution, avoiding dilution, as much as possible, and assisting the solution of the Sb_2S_3 by heating. Filter off the CuS (which may be accompanied by small amounts of PbS), dissolve it in HNO_3, (separate Pb if desired by H_2SO_4 etc.), and determine Cu by standard KCy.

The KOH solution containing Sb should not be over 40 cc. Add 50 cc. conc. HCl, and 1 gm. $KClO_3$, boil out free Cl, filter through mineral wool if necessary, cool, add 1 gm. KI, 1 cc. CS_2 and titrate for Sb with tenth normal $Na_2S_2O_3$ solution.

As is determined in a separate portion by the method sketched out for the qualitative examination. If any is present, it must be allowed for in reckoning up the results from the I titration.

Bi and Cd would go with the Cu as sulphides. Ni or Co partly with that precipitate and partly with the SnO_2.

Volumetric for Arsenic. Engel and Bernard. (C. Rend. CXXII. 390.) Render alkaline, and concentrate to 20 to 40 cc. Add three times its volume of HCl (of 22° B). Then add a decided excess of hypophosphorus acid—4 to 10 cc. of a solution of 35° B, according to the proportion of As presumed to be present. Let stand 12 hours, warm on the water bath—add an equal volume of boiling water—filter and wash with boiling water until all acid is removed. The precipitate is As in the elemental form. Put paper and all in the vessel in which precipitation was effected and add $N/_{10}$ I solution from a burette. When the solution holds the iodine color, the stage of formation of As_2O_3 has been just passed, wait two or three minutes to allow it to complete itself, and then add 50 cc. of water, and 10 cc. of a saturated solution of $NaHCO_3$. Then continue the titration with $N/_{10}$ I solution using starch for the end reaction which occurs when all As is transformed to As_2O_5—1 cc. $N/_{10}$ I = 0.0015 As.

Arsenic in Alloys of Tin and Lead. De Koninck. (Wed. Tyds. Pharm. VII. 330.) The alloy is placed in a small retort, covered with a mixture of HCl and Fe_2Cl_6 solution, and slowly distilled. The retort delivers into a Peligot bulb tube containing a little water. Very little H and practically no As H_3 is evolved. After distilling nearly to dryness the As is separated and determined in the distillate by H_2S.

Arsenic in Presence of Selenium. Dawydow. (Chem. Zt. Rep. XIX. 70.) Se interferes with the Marsh test, also with the $SnCl_2$ test. It is recommended to separate out by H_2S, filter, dissolve out As_2S_3 with $(NH_4)_2CO_3$, and thus separate the As before applying these tests.

Arsenic in Crude Oil of Vitriol. Hattensauer. (Zts. Angew Chem. 1896, 130.) 500 cc. of the acid are diluted with the same bulk of water, and, after cooling 500 cc. dilute HCl (1 : 2) are added. (This will hold up $PbSO_4$ or PbS.) H_2S is then passed for an hour, and the As_2S_5 filtered off for determination. The precipitate was found to be free from Pb, nor was the the filter paper attacked in experiments with the method.

Antimony in Ores, Etc. Clark. (J. S. C. I. XV. 255.) The fire assay is always untrustworthy, but may at times give (by accident) nearly the same results as the wet analysis, on account of the impurities in the button obtained. For wet analysis, the author prefers Mohrs' titration method (viz., oxidation by $N/_{10}$ I solution in alkaline bicarbonate solution). The ore or alloy is treated with HCl so long as there is any action, then solid I is added and heat applied until complete solution of the metal has been effected. Boil out the excess of I, cool, dilute and add a little starch. If any blue appears, add dilute Na_2SO_3, drop by drop until it disappears, then add Rochelle salt, render alkaline, add excess of $NaHCO_3$ and titrate.

Cu, if present, causes low results. In that case it is best to precipitate out both as sulphides, dissolve out the Sb_2S_3 with KOH, and then work with the Sb thus freed from the Cu.

If As is present, it can be removed by boiling down the HCl solution

of the original substance to one-third its bulk, once or twice with strong HCl, before preparing the solution for titration.

Reducing Potassium Platin-Chloride. Sonstadt. (J. Lond. Chem. Soc. LXVII. 984.) Mixing with twice its weight of Hg and heating carefully, will afford volatile Hg_2Cl_2 and $HgCl_2$ together with the excess of Hg, and leave behind a porous mass of Pb with KCl, which latter can be washed out with water. Pure Hg will afford a perceptible precipitate of Pt from its salts even in the presence of 3 million parts of water.

Selenium: Gravimetric Estimation. Pierce. (Am. J. Sci. [4] I.) Boiling for 20 minutes an HCl solution after adding KI, afforded elemental Se in the black modification which could be filtered on asbestos felt, washed, dried and weighed. When less than 0.1 gm. of Se was present, very good results were obtained; with larger amounts some KI appeared to precipitate with the Se, which assumed a pasty molten condition. If the dilution was made very considerable (400 cc.), and 3 gms. of excess of KI was used, satisfactory results were obtained with over 0.4 gm. Se in one determination. The results in every case were a little high.

Determining Selenious and Selenic Acid. Gooch and Pierce. (Zts. Anorg. Chem. XI. 249.) The methods depends on the following: As_2O_5 boiled with KI and H_2SO_4 affords As_2O_3 and I is expelled. SeO_2 boiled with KI and H_2SO_4 affords Se and I is expelled. If a mixture of As_2O_5 and SeO_2 is boiled with a limited amount of KI, say sufficient to reduce the major part of the As_2O_5, the SeO_2 reacts first, and less As_2O_3 will be formed. The amount of As_2O_3 remaining at the end of the operation may be determined by neutralizing, adding $KHCO_3$ and titrating with normal I solution. The conditions therefore required are: Addition to the SeO_2 solution of a known amount of KI; addition of As_2O_5 solution in amount sufficient to react with the KI added, acidifying with H_2SO_4 and boiling gently for some time. After boiling down from 100 cc. to about 35 cc., the solution is cooled, neutralized, etc., as suggested above. With SeO_3 it was found necessary to reduce to SeO_2 before applying this method. Boiling with HCl is inadmissible on account of the volatility of $AsCl_3$. Boiling with HBr, is not open to this objection under the conditions produced. It is therefore recommended to boil the SeO_3 solution first with KBr and H_2SO_4, and then to apply the treatment prescribed for determination of SeO_2.

Electrolytic Determination of Iron, Nickel and Zinc. Nicholson and Avery. (J. Am. Chem. Soc. XVIII. 654.) In separating Fe strong currents and free NH_3 favored the separation of C along with the deposit. This did not occur when only formates or oxalates were present. The addition of borax to ammoniacal oxalate solution greatly facilitated the precipitation of Fe.

Separation of Ni was easily effected. No C was found in the deposit.

With Zn the deposition was readily effected. The difficulties encountered were chiefly the formation of a spongy deposit and liability to oxidation. These were prevented by the use of formic acid in the solution.

Electrolysis of Solutions Containing Manganese and Tin. Engels. (Zts. Angew. Chem. 1896. 238.) The addition of a salt of hydroxylamin prevents separation of MnO_2. To the solution of tin salt, cleared by addition of a few cc. of oxalic acid if turbid, is added 0.3 to 0.5 gm.

hydroxylamin sulphate or chloride, 2 gms. $NH_4C_2H_3O_2$, and 2 gms. $H_2C_4H_4O_6$. The solution is diluted to 150 cc., warmed to 60 or 70° C., and then a current of strength $ND_{100} = 0.99$ to 1 amp. passed through it. The analysis will be finished in three hours with a gramme of tin salt. The dish should be covered with a well-fitting cover to prevent loss by evaporation.

Electrolytic Separations. Heidenreich. (Ber. XXIX. 1585.) Examination of methods recommended by E. F. Smith. The solutions were uniformly 120 cc., covering 100 cm.^{2} of surface (platinum dish). The details were:

Iron. Solution contained 50 cc. 10% $Na_3C_6H_5O_7$ and 2 cc. 10% $H_3C_6H_5O_7$. Current 0.6 to 0.97 amp.; 4.34 to 5.6 volts. Time 4 to 6½ hours. With a solution of ferri potassium oxalate, 0.54 to 0.62 amp., 4.5 to 5 volts. Time, 7¾ hours. In both cases the deposited iron contained a little carbon.

Copper. Good results were obtained in a solution containing Na_2HPO_4 and H_3PO_4; 2.4 to 2.6 volts. Time, 17 hours.

Cadnium. No satisfactory results could be obtained either with acetic acid solutions or with phosphate solutions.

Silver. No success with phosphate solutions; precipitate spongy.

Molybdenum. Smith's method, of separating as Mo_2O_3 and then oxidizing to MoO_3 for weighing, afforded no satisfactory results. Precipitation was incomplete after 85 hours, and losses were also unavoidable in oxidizing to MoO_3.

Uranium. No success with acetate solutions.

Separation of Pb from Hg. Successful with a solution containing 20 to 30 cc. HNO_3 (of Gr. 1.3 to 1.4) in 120 cc. If the acid was weaker the PbO_2 would scale off. Current, 0.2 to 0.5 amp.

Ag from Pb. Unsuccessful.

Cu from Zn. With about 4 cc. of HNO_3 (Gr. 1.3) in 120 cc. the separation was successful, provided the tension did not surpass 1.4 volts. Most of the Cu separates quickly. The complete separation required 18 to 20 hours.

Cu from Cd. No satisfactory results in HNO_3 solutions. Smith and Wallach's method with cyanide solution was not tried, as the tension of the current is not given by them.

Ag from Cu. 2 gms. KCy (and in one case 6 gms. KCy) added to the solution for electrolizing; 0.03 to 0.19 amp.; 1 to 1.39 volts. Time, 4 to 8 hours. Satisfactory. Rapidity of operation increased by warming to 65–75°.

Ag from Zn. 2 to 2.5 gms. KCy added (double cyanides); 0.02 to 0.08 amp.; 1.8 to 2.15 volts. Time, 15 to 20 hours when cold; 6½ hours (at 60°). Comment similar to the above.

Hg from Zn. Solution of double cyanides; 0.03 to 0.08 amp.; 1.65 to 1.75 volts. Time, 5 and 14 hours. Easily accomplished. The Hg and KCy cause the Pb dish to suffer.

Hg from Ni. Solution of double cyanides; 0.03 to 0.08 amp.; 1.2 to 1.6 volts. Time, 5½ hours or over night. Satisfactory.

Halogens: Indirect Determination. Schierholz. (Monatsheft. f. Chem. XIII. 1.) This method will serve when the proportions of the halogens present is not too small.

Divide the (neutral) solution to be tested into two equal parts. Titrate one part with tenth normal $AgNO_3$ as usual. Add a drop of HCl. Filter off and weigh the precipitate $= a$. Calculate the Ag therein from the volume of $AgNO_3$ solution used $= c$. A correction of 0.1 to 0.2 mgs. Cl should be made for the Ag which has served to give the end reaction.

To the other half, add about one-tenth as much $AgNO_3$ as before, stir in and observe the color of the precipitate. If it has a rather pale tint of AgBr, further addition of $AgNO_3$ will give the clear white AgCl. The object is to precipitate all I and Br with as little chloride as possible. Then add about 3 gms. of pure KBr, and run in $AgNO_3$ until as much has been added as was added to the first half. Boil, concentrate a little, and then filter and finally weigh this precipitate $= b$. Then $(b - c) \times 5.006 = AgI$ and $(b - a) \times 3.223 = AgCl$, and the sum of these two deducted from a gives AgBr.

The solubilities of these silver salts were found to be:

Dissolved 1 in 5 of H_2O	Dissolve of		
	AgCl	AgBr	AgI
100 gms. NaCl	485 mgs.	480 mgs.	0.95 mg.
100 gms. KBr		3010 mgs.	525 mgs.
100 gms. KI			89800 mgs.
95 gms. NaCl + 10 gms. KBr		75 mgs.	1.2 mg.

On this he has based a method for determination of small amounts of I, by treating the silver salts with moderately concentrated solution of NaCl. When there is present 3 (or less) parts I to about 20 Br and 3000 NaCl, it is applicable. With more I or Br, the Pd method is preferable.

Determination of Chlorides, Hypochlorites, Chlorates and Perchlorates. Carnot. (Bull. Soc. Chim. XV. 393 and 397.) In case of a mixture of the first three or of all four, the *hypochlorite* is first determined by means of standard Na_3AsO_3, using a "spot test" with KI and starch. Then acidify with H_2SO_4, warm to nearly boiling, and add a known amount of ammonio-ferrous sulphate; stopper up to prevent access of air, cool somewhat and titrate with permanganate. The amount of iron oxidized by the solution gives the measure of the *chlorate* present. Perchlorate is not decomposed by this reaction.

To this solution a drop or two of $FeSO_4$ is added to destroy the excess of permanganate, and then an excess of standard $AgNO_3$ solution is added. This precipitates all the Cl originally existing in the solution as chloride, hypochlorite and chlorate. Titrate back the excess of Ag by standard NH_4CNS (Volhard's method) and from the results all the Cl present in these three forms may be calculated. Deducting that due to hypochlorite and to chlorate, leaves the amount of Cl as *chloride.*

The *perchlorate* must be decomposed by heat, but as the temperature necessary for decomposition will volatilize some KCl, some of the dry material must be weighed out in a platinum crucible and covered with a layer of dry sand at least 2 cm. deep. Then, on applying the flame so that only the bottom of the crucible is made red hot, and maintaining the heat for 20 to 30 minutes, loss by volatilization is avoided, and all forms of Cl are brought to chlorides. Leach out with water, titrate with standard $AgNO_3$ and obtain perchlorate by difference.

Detecting Iodine in Presence of other Halogens. Ludwig. (Ber. XXIX. 1454.) Ethereal oils which have been distilled in air, contain sufficient

ozone to set free I. The same is true of the aldehydes when used even in very dilute solutions. Very small amounts of the aldehyd should be used. The solution should be neutral and contain no reducing agents or mercury salts. Starch solution, or else CS_2 may be afterward used to make the presence of the free I more evident. The latter is regarded as the more satisfactory.

Volumetric for Iodine. Riegler. (Zts. Anal. Chem. XXXV. 305.) The reaction between an iodide and iodic acid is as follows:

$$6HIO_3 + 5NaI = 5NaIO_3 + 3H_2O + 6I.$$

The method consists in using an excess of a standard solution of HIO_3, removing the I set free by shaking with petroleum ether, and then determining the excess of HIO_3 remaining by means of standard $Na_2S_2O_3$. The reaction is:

$$6Na_2S_2O_3 + 6HIO_3 = 3Na_2S_4O_6 + 5NaIO_3 + NaI + 3H_2O.$$

Any excess of HIO_3 gives free I. 176 gms. HIO_3 correspond to 24.8 gms. crystallized $Na_2S_2O_35H_2O$. The iodide solution, which must not be over 1% in strength, is mixed in a parting funnel with an equal volume (or sufficient excess) of the HIO_3 solution (17.6 gms. per litre) well shaken, 20cc. of petroleum ether added. After standing about 15 minutes, the aqueous solution is run off into a beaker. The petroleum ether containing the most of the free I is poured out, the aqueous solution returned to the funnel, and again shaken with 15 cc. of fresh petroleum ether, to remove the last traces of I. The aqueous solution is then run off and titrated with the standard $Na_2S_2O_3$, using starch as indicator. The I thus found $\times 1.368$ gives KI; $\times 1.1811$ gives NaI.

Commercial Hydro-Fluoric Acid. Stahl. (J. Am. Chem. Soc. XVIII. 415.) The principal impurities are H_2SiF_6 and H_2SO_4. Specific gravity is a guide as to the strength of the acid only to a limited extent. A platinum hydrometer is used for that purpose. In manufacturing all fluorspars have been found to contain SiO_2 from a few tenths up to 3%. American fluorspar contains usually about 1.5. This is determined by moistening 1 gm. of the pulverized spar in a Pt dish weighed with a spatula, with HF, and drying on a water bath. This operation is repeated, and the loss is reckoned as SiO_2. Carbonate, if present, must be removed by preliminary treatment with $HC_2H_3O_2$. Moisture also must be removed by drying out before applying the HF.

To examine the acid, weigh out as follows:

No. 1. 2 gms. in a small Pt crucible.

No. 2. 2 gms. in large Pt crucible.

No. 3. 4 gms. in Pt dish.

No. 1 is used for total acidity. The crucible is placed in a large Pt dish, into which is run normal NaOH, in amount estimated to be nearly enough to neutralize. The crucible is then overturned and the titration completed. Phenolphthalein has been found to be the best indicator. At the end the solution must be warmed to about 50° C., and the alkaline color must be permanent at that temperature.

No. 2 serves for H_2SiF_6. After diluting with about 5 cc. of water, add by degrees 2 gms. K_2CO_3 (not enough to neutralize completely) then 15 cc. of 50% alcohol, and as much 95% alcohol as water. Stir in, let stand one hour at least, filter off K_2SiF_6, wash free from acid with

50% alcohol, place paper and precipitate in a Pt dish, add 25 cc. water, warm to 50° and titrate, using phenolphthalein as before. The reaction is:

$$K_2SiF_6 + 4NaOH = 4NaF + 2KF + SiO_2 + 2H_2O.$$

No. 3 is for H_2SO_4. Heat on a water bath until acid is no longer volatilized, dilute and titrate.

Calling results in No. 1 $= a$, in No. 2 $= b$, in No. 3 $= c$.

$$a - \left(\frac{3}{2}b + \frac{c}{2}\right) = \text{per cent. free HF}$$

$b \times 1.8 =$ per cent. H_2SiF_6

$c \times 1.2 =$ per cent. free H_2SO_4.

The acids tested were found to contain usually 40% or more of HF, 2.7 to 10 of H_2SiF_6, and about 1 of H_2SO_4.

Pyrrhotite in Pyrites. Cone. (J. Am. Chem. Soc. XVIII. 404.) The Fe_7S_8 (pyrrhotite) yields its S with difficulty, or not at all, in burning for the manufacture of H_2SO_4.

To separate it, grind the ore so as to pass a 60 mesh sieve, (*not finer*). Weigh out 13.74 gms. and spread that out on a sheet of glazed paper. Stir several times with a magnet, which takes out the Fe_7S_8, which is removed from the magnet by aid of the armature and a brush. Work over the separated portion again and again, 5 or 6 times in all. The material separated is then finely ground, and the S therein determined, giving S in Fe_7S_8. Total S is determined in another portion of the sample.

A method based on the evolution of H_2S from Fe_7S_8 by the use of dilute acid (which is not the case with FeS_2,) is usually untrustworthy as the sample may contain blende or some similar sulphide.

Sulphur in Pig Iron. Auchy. (J. Am. Chem. Soc. XVIII. 406.) Recommends strongly Drowns' method—passing the gases, evolved on treating with HCl, through $K_2Mn_2O_8$ solution, and subsequently weighing as $BaSO_4$. The use of an alkaline (KOH) solution of $K_2Mn_2O_8$ is recommended. To destroy the excess of $K_2Mn_2O_8$, $H_2C_2O_4$ is used. Evaporating to remove SiO_2 before adding $BaCl_2$ is not regarded as essential. The results of numerous experiments are given in detail.

Sulphur in Illuminating Gas and in Coal. Mabery. (Am. Chem. Jour. XVIII. 207.) The gas is burned inside of a combustion tube in a current of air, the products of combustion being drawn through a measured amount of standard NaOH, in a U tube containing glass beads or broken glass, the solution being titrated after the operation, using methylorange indicator.

The combustion tube is 45.5 cm. long, with a constriction 30 cm. from the forward (meter) end. The tube delivering the gas from the meter is pushed in so as to terminate at the constriction. The air is delivered into the combustion tube by a tube which is cut off near the cork through which it and the gas tube passes. The U tube, which should be of large diameter, is connected on the one side with the combustion tube, on the other with a water pump or other form of suction pump. A tolerably rapid current of air is necessary. Practically no SO_2 appeared in the NaOH solution.

In coals, asphalt, etc., essentially the same method was found to be successful, the material being introduced into the combustion tube in a platinum boat and burned in a current of air.

Solubility of Barium Sulphate. Fresenius and Heirz. (Fres. Zts. Anal. Chem. XXXV. 180.) If solutions of a strength suited to produce 5 mgms. in 400,000 times its weight of water are mixed, a slight separation is observed after 24 hours, whereas such is not apparent if 4 mgms. only can be produced. Hence in the nascent state 1 part of $BaSO_4$ is soluble in 100,000 of water. The presence of $BaCl_2$, or of H_2SO_4 in the solution diminishes the solubility, bringing it down to 1 in 400,000 or less (with H_2SO_4).

In presence of 10% solution of NH_4Cl, the solubility of $BaSO_4$ in the nascent state is about 1 in 10,000. H_2SO_4 brings this solubility down to 1 in 400,000, $BaCl_2$ to 1 in 50,000. Stronger solutions of NH_4Cl have a greater solvent action. NaCl acted similarly to NH_4Cl, though not quite so strongly.

In HNO_3 (8%) nascent $BaSO_4$ was soluble to the extent of 1 in 7,300. In HNO_3 of 10%, H_2SO_4 brought the solubility down to 1 in 400,000, $BaCl_2$ to 1 in 33,000.

In HCl (7 to 8%) the solvent action on nascent $BaSO_4$ was essentially the same as with HNO_3 (1 in 7,300) H_2SO_4 or $BaCl_2$ decreased the solubility to a greater extent than did HNO_3.

Persulphates. Ulzer. (Mitth. Tech. Gew. Mus. Wien. 1895, 11 and 310.) Methods of analysis depending on the liberation of I or Cl by the available O were found to be inaccurate, as also treatment with excess of standard $H_2C_2O_4$. The method recommended consists in heating 0.3 gm. of the substance in a valved flask with a known amount of $(NH_4)_2SO_4$, $FeSO_4$ and dilute H_2SO_4 for half an hour, and then titrating the amount of unchanged ferrous salt remaining by permanganate.

Sulphides, Sulphites, Thiosulphates and Sulphates in presence of each other. Richardson and A. Kroyd. (J. SCI. XV. 171.)

Sulphates. Add 5 gms. tartaric acid to the solution and precipitate with $BaCl_2$ in the cold. Filter. The precipitate may contain some $BaSO_3$, which can be removed by afterward washing with hot dilute HCl and boiling water.

Sulphides. Titrate with NH_4 solution of Zn. (vid Sutton Vol. Anal. Schwartz's method.) The strength of the solution is such that 1 cc. = 0.0016 gms. as sulphide.

Sulphites and Thiosulphates. Add NH_4 solution of Zn to remove sulphides. Then add methyl orange indicator and bring to neutrality to that indicator (filter off ZnS). The solution should now contain acid sulphite and thiosulphate. Titrate with tenth normal I solution. This affords tetrathionate (say $Na_2S_4O_6$ from $Na_2S_2O_3$) and acid sulphate (say $NaHSO_4$ from $NaHSO_3$). Then titrate with tenth normal alkali. Since the methyl orange shows the neutral tint to $NaHSO_3$, but gives the acid color with $NaHSO_4$ until it has been neutralized to Na_2SO_4, the last titration gives the measure of the sulphite. Calculate the amount of I which must have been used to produce the sulphite thus found, and the remainder of the I used is to be calculated as the measure of the thiosulphate, the equations being

$$2Na_2S_2O_3 + I_2 = Na_2S_4O_6 + 2NaI$$
$$NaHSO_3 + I_2 + H_2O = NaHSO_4 + 2HI.$$

Phosphorus in Phosphor Bronze. Oettel. (Chem. Ztg. XX. 19.) 3 to 10 gms. of the bronze are digested with HNO_3 and the SnO_2 resulting

(which retains the P_2O_5); after washing, drying and igniting, is fused with three times its weight of KCy in a porcelain crucible. On cooling and leaching out with water K_8PO_4 goes into solution. Acidify with HNO_3 and boil; cool, and pass H_2S to remove small amounts of Cu, Pb and Sn which may remain, filter, remove excess of H_2S by boiling and adding Br water and precipitate in the usual manner with magnesium mixture. As does not interfere, being removed by the different steps of the process.

Volumetric for Phosphoric Acid. Veitch. (J. Am. Chem. Soc. XVIII. 389.) Pemberton's method as modified by Kilgore. (vid QUARTERLY XVI. 179 and XVII. 324.) After detailing numerous experiments, the conclusions are:

1. The molybdate solution to which HNO_8 has been added, standing one-half hour at 40°–50°, gives results comparing very favorably with the gravimetric.

2. While the use of tartaric acid in the molybdate solution gives good results, it possesses no advantage, and the extra time of standing makes it not so desirable.

Phosphates in Fertilizers. Bryant. (J. Am. Chem. Soc. XVIII. 491.) observes that P_2O_5 in bone, tankage, etc., is of more value than that in undecomposed phosphate rock, though it may by the ordinary treatment be rated as "insoluble." He proposes the separation of the heavier phosphate rock by specific gravity after washing out the "soluble" and drying. The separating solution is made by dissolving 75 gms. KI and 100 gms. HgI_2 in 350 cc. of water, and evaporating to a sp. gr. of 2.26. Bone phosphate, etc., is less than this. Iron or aluminum phosphate, silica, phosphate rock, fluorite, etc., are heavier.

Phosphates in Thomas Slag. Mach and Passon. (Zts. Angew. Chem. 1896. 130.) 100 cc. of the solution (obtained by Wagner's method) is placed in a half litre flask and boiled down with 10 cc. conc. H_2SO_4. 15 cc. conc. HNO_3 and a drop of Hg until colorless. After cooling, 20 cc. of a 10% solution of NaCl is added to precipitate Hg, and the contents of the flask is mixed into a 200 cc. flask, which is then filled to the mark and 100 cc. of the clear solution taken, mixed with 100 cc. of the ammonium citrate solution, 25 cc. of Mg. mixture added, and the remainder of the operations conducted in the usual manner.

Detecting Boric Acid in Milk, Wine, Etc. Doherty. (Proc. Lond. Chem. Soc. 1896. 101.) The material is mixed with NaC_2O_3 dried and thoroughly charred, then extracted with water, acidified with HCl and evaporated in a porcelain boat enclosed in a piece of combustion tubing, one end of which has been drawn out to a jet, through which illuminating gas is passed. The jet delivers into a short piece of tubing with holes at the sides for admitting air, forming a glass Bunsen burner. On lighting the gas at the end of the second tube, the green flame is easily seen, when BoO_3 is present—provided, of course, that the boat containing the mixture is kept warmed.

Decomposition of Silicates by Boric Acid. Jannasch and Heidenreich. (Zts. Anorg. Chem. XII. 208.) Obtain H_3BO_3 absolutely free from alkali, by dissolving and recrystallizing repeatedly from a good quality of commercial acid. Dehydrate by fusing 3 to 5 gms. at a time in a platinum crucible, dipping the lower half of the hot crucible in cold water after fusion to crack up the cake by the sudden cooling, and render it

easily removable. Pulverize in an agate mortar and preserve well protected from moisture over $CaCl_2$.

Of the silicate take at least 1 gm. weighed out in a (50 to 60 gm.) Pt crucible. The amount of B_2O_3 to be taken depends on the decomposability of the silicate. If readily decomposed 3 to 4 gms. may suffice, if more difficultly, 5 to 6 times or more. For feldspar use 8 times the weight, mix intimately with a glass rod and heat cautiously with a low flame at first to expel water. As the heat is gradually raised at a certain point there will be a strong foaming and frothing which may be checked before becoming too serious by temporarily removing the crucible cover. The insertion of a small piece of bent Pt wire (stout) for stirring, etc., may be advantageous at this stage. Eventually the fusion is brought to a quiet condition, which is maintained for some time with the full heat of the burner, finishing with a few minutes over the blast lamp. The whole fusion should occupy 20 to 30 minutes. Set the hot crucible in cold water, covering it well and weighting down the cover to prevent loss. The melt can be easily detached when cool, and is treated in a Pt dish with 100 to 150 cc. of boiling water and about 50 cc. of HCl. Rinse out the crucible separately with a similar mixture of water and acid, and unite the solutions. Evaporate to complete dryness. To remove the B_2O_3, use anhydrous methyl alcohol saturated with dry HCl, freshly prepared as follows: Place about 250 cc. of the methyl alcohol in a wash bottle, and pass a rapid stream of anhydrous HCl into it through the delivery jet for 2 to 3 hours, keeping the flask immersed in cold water. Wet down the mass from the fusion with 60 to 75 cc. of the prepared methyl alcohol, and evaporate off on a water bath with constant stirring. Two treatments of this kind probably remove the B_2O_3 almost entirely, but it is safe to repeat it two or three times. The dish should fit the ring of the water bath closely, that the stream may not be evolved too near to the dish. Afterward dry the mass for fully an hour at 110°, digest with HCl, filter off SiO_2 and proceed with the analysis in the usual manner.

Soluble Silica in Clays. Michælis. (Chem. Ztg. XIX. 2296.) Lunge's assertion (vid QUARTERLY XVII. 321) that Na_2CO_3 solution is suited for this purpose is disputed, the author finding that a 10% NaOH is necessary. A case is cited in which Na_2CO_3 showed 1 to 3% of soluble silica, whereas the true proportion as determined by NaOH was about 16%.

Carbon Dioxide: Iodometric method. Phelps. (Am. J. Sci. [4] II. .) The process consists in fixing the CO_2 by use of a known amount of $Ba(OH)_2$ in solution, in a partially exhausted flask, then adding excess of I solution to convert the excess of $Ba(OH)_2$ into iodide and iodate $6\ Ba(OH)_2 + 6\ I_2 = Ba(IO_3)_2 + 5\ BaI_2 + 6\ H_2O$, and finally titrating the excess of I by standard As_2O_3. It was found necessary to boil after adding the I solution to destroy hypoiodite which would affect the As_2O_3 in titrating. The flask in which the boiling is performed must be connected so that the escaping steam passes through KI that the free I may not be lost.

Carbon Dioxide in Air. Henriet. (C. Rend. CXXIII. 2. 125.) The air is drawn through KOH of known strength. Phenol phthalein is then added, and the cold dilute solution titrated with standard H_2SO_4. The end reaction occurs when all the CO_2 is in the form of $KHCO_3$. On this a calculation can be based.

Absorbent for Nitrogen in Argon Determination. Warren. (C. N. XXIV. 6.) CaO or $Ba(OH)_2$ is saturated with strong solution of LiOH, mixed with Mg powder, and the mixture reduced in an atmosphere of H at as low a temperature as possible. The resulting mass contains metallic Li, as also small amounts of Ba or Ca, and will rapidly absorb N, so rapidly indeed that it may become incandescent.

"Absolute Method" for Nitrogen. Dunstan and Carr. (Proc. Lond. (Chem. Soc. No. 161. Feb. 1896.) In determining N in aconitine by soda lime, results closely according with theory (2.1%) were obtained. On applying the "absolute method" gas volumes corresponding to 4% N and over, were obtained. Investigation disclosed the fact that methane was mixed with the N, which was oxidized very slowly and imperfectly by red hot CuO. The point is naturally suggested that error of the same kind may occur in the application of the "absolute method" to other nitrogenous substances.

Test for Nitrites. Sabatier. (C. Rend. CXXII. 1417.) Place a drop of the solution to be tested on a white porcelain, add a drop of conc. H_2SO_4, and then a few grains of Cu_2O. If a nitrite is present, a violet or purple tint will appear. The reaction is less sensitive than that with metaphenylene-diamine.

Determining Nitric Acid. Péchard. (C. Rend. CXXI. 758.) On mixing a drop of a solution containing nitrate with a drop of concent. H_2SO_4 and adding a fragment of brucine, the well known red coloration appears. At that point, if distilled water is added drop by drop, at a certain point of dilution the coloration disappears. At this point the liquid contains 0.0000207 gm. of nitrogen per cc. On conducting the operation so that volumes of the liquids used can be measured, a quantitative estimation can be effected. If pure HCl is used, instead of H_2SO_4, only the nitrous nitrogen is estimated by this means.

Nitrates in Water. Alessandri and Gassini. (Bolet. Chem. Pharm. 1895. 490.) Add to the warm residue from evaporation, strong HCl containing a few drops of phenol. If only traces of nitrates are present, on heating an intense red-violet coloration appears, which becomes emerald green on adding ammonia.

Oxygen in Water. Romijn. (Rec. Trav. Chim. Pays. Bas. XV. 76.) A pipette having stopcocks above and below is used (capacity about 220 cc.). The tube above the upper pipette is graduated. After filling the pipette with the water to be tested and closing both cocks, 1 cc. of a solution containing 0.120 gm. $MnCl_2$ and 0.085 gm. KI is placed in the graduated tube; then by opening first the upper cock and then the lower, this solution is drawn into the water. After shaking, 1 cc. of asolution of Rochelle salt (10 gms. in 12 cc.) and 1 cc. NaOH (1 in 10), are introduced in the same manner. After shaking again and allowing to stand for 10 minutes, 1 cc. of a 25% solution of HCl is added, the water run into an Erlenmeyer flask and the I set free is titrated with standard $Na_2S_2O_3$. A special form of apparatus has been devised for the process.

Estimating Oxygen by Pyrogallol Solution. Clowes. (J. S. C. I. XV. 170.) Using a solution containing 10 gms. pyrogallol and 24 gms. KOH in 100 cc., it was observed that when the proportion of O in the gaseous mixture analyzed passed 28% CO was evolved. Increasing the proportion of KOH in the solution diminished this error, and when

brought up to five times as much as that above (viz. 120 gms.), the evolution of CO was inappreciable. Alkaline solution of hydroquinone was found to be effective, though slow in absorbing O without evolution of CO. The solution used contained 18 gms. hydroquinone, and 24 gms. KOH in 100 cc.

Ozone and Hydrogen Peroxide. Engler and Wild. (Ber. XXIX. 1940) The authors find that H_2O_2, even in the most diluted form, is decomposed by CrO_3, whether the same is in solution or in solid form, whereas ozone produces no effect. Hence CrO_3 is a very delicate test for H_2O_2 whether ozone is present or not. They have not found any very sensitive reagent for ozone in presence of H_2O_2. The best is paper moistened with $MnCl_2$ solution which turns brown when ozone is present. The same effect is produced by ammonia or by $(NH_4)_2CO_3$, but the brown produced by ozone becomes bluish on moistening with guaicum solution, which is not the case with the ammonium brown. It is advised to destroy H_2O_2 first by use of CrO_3 solution, and then to apply the tests for ozone.

New Reagent for Hydrogen Peroxide. Bach. (Chem. Ztg. XIX. 37.) A solution is made containing 0.03 gm. $K_2Cr_2O_7$, and 5 drops (0.25 gm.) of anilin per litre. Also a 5% solution of $H_2C_2O_4$. 5 cc. of the $K_2Cr_2O_7$ reagent is shaken a few times with 5 cc. of the solution to be tested, and one drop of the oxalic solution. If H_2O_2 is present, a violet red coloration develops. The degree of sensitiveness is 1 in 1,400,000. Nitrogen oxides give no reaction, but bleaching powder and HClO do. The H_2O_2 from fresh green leaves can be detected by this reagent; 20 gms. of the leaves are treated with 75 cc. of a 0.1% $H_2C_2O_4$ solution, and 5 cc. of the solution tested as above.

Determining Hydrogen by Palladivus Chloride. Campbell and Hart. (Am. Chem. Jour. XVIII. 294.) The $PdCl_2$ solution was made by dissolving 5 gms. Pd wire in 30 cc. HCl with 1 to 2 cc. HNO_3. The solution was evaporated just to dryness on the water bath redissolved by warming in 25 to 33 cc. of water with 5 cc. HCl, and then diluted to 750 cc. The pipette used was the ordinary single Hempel absorption pipette, arranged so as to be easily detached from the stand. After introducing the solution and then the gas to be analyzed, the pipette was closed and placed in a boiling water bath for 2 hours, unless the amount of H exceeds 65 cc. or the pipette has been previously used, in which cases a longer time is required. Absorption is retarded by the use of strongly acid solutions.

Water, Test for Contamination. Nordlinger. (Fres. Zts. Anal. Chem. XXXV.) Cresol or saprol, when added to the contents of a cesspool may serve to indicate whether the contents of the cesspool pass into a water supply. The odor of one part in a million is perceptible, and the taste is apparent if one part is present in two million.

Boiler Scale. Reichard. (Chem. Ztg. XX. 65.) Silica was found to be a cause of "scale" in one case. The water contained 8.6 total solids per hundred thousand, in which were CaO 2.08, MgO 0.22, SiO_2 2.6 and alkalies (weighed as chlorides) 2.35. The scale consisted chiefly of SiO_2 and CaO.

Degree of Oxidation of Oils. Bishop. (J. Pharm. et Chim. 1896. 55.) Precipitated SiO_2 is suitable for dividing up the oil, but used alone the oxidation proceeds two slowly. By addition of 2% of manganese resinate the test can be conducted in a reasonable time. The commercial

resinate should be purified by dissolving in ether or petroleum spirit, filtering, and evaporating off the solvent The dry resinate (found to contain 9.8% MnO) is powdered and bottled for use.

Weigh out 18 gms. of the oil, add to it 0.2 gm. of the resinate, and cause the same to dissolve by constant stirring over a water bath; cool, weigh out in a flat dish (with rod), 1 gm. of SiO_2 and add to it drop by drop 1.02 gms. of the resinated oil, mixing it in thoroughly. Spread the mass over the bottom of the dish, and set it aside at a temperature of 17 to 25° C. for drying oils, and of 20 to 30° C. for other oils. Weigh after six hours and twice again in 24 hours, stirring up after each weighing. The maximum increase in weight multiplied by 100 gives the degree of oxidation.

Analysis of Mortar. Dibdin and Grimwood. (Analyst. XXI. 197.) Crush the sample and mix thoroughly; weigh out 10 gms. in a platinum dish and dry in an air bath in the usual manner for determining water by loss. The absorption of CO_2 is insignificant in amount. Weigh out another 10 gms., stir up in a beaker with solution of 10% HCl, allow to stand one minute, pour off solution and suspended earthy matter, and repeat this until the supernatant liquid, on standing for one minute, is perfectly clear. Wash, dry and weigh the residue as "sand." Filter off the "earthy matter," wash dry and weigh. In aliquot portion of the solution determine SiO_2, Fe_2O_3, Al_2O_3, CaO and SO_3. (The presence of MgO is ignored by the authors. Abs.) The dried sample is ignited at low red heat and the loss on ignition noted. It is then moistened with water to hydrate the CaO, dried at 220° F. and reweighed.

Ordinary Mortars. Commercial lime contains about 80% CaO. In England crushed brick is much used instead of sand for making mortars, and in some cases the bricks contain $CaCO_3$. The mixtures are of course usually made by volume. Two ratios are calculated, viz., that of lime to sand (or broken brick) and that of lime to all other matters (excluding water). The total CaO (as CaO, $CaCO_3$ and $CaSO_4$) is increased by one-fourth to obtain the *weight* of commercial lime used. This figure must again be increased by one-fourth to obtain the *volume* used, as compared with that of the sand or broken brick, *e. g.*, in a sample examined 10.89 of CaO was found. $10.89 + 2.72 = 13.61$ = weight of commercial lime, and $13.61 + 3.40 = 17.00$ = volume of commercial lime. In this case broken brick being calculated as 48.75, the ratio of lime to brick by volume was 17 : 49, or nearly 1 : 3.

Cement Mortars. The calculation is made on the soluble silica found. This may be checked by the proportion of lime. It may be assumed that a fair average Portland cement will contain 18% of soluble silica and 60% CaO. The percentage of soluble silica multiplied by 5.55 should give approximately the *weight* of cement used. To this figure add one-eighth to obtain the *volume* relatively to that of the sand, and calculate as before.

The data used in the calculations of volume were:

18.5 cc.	commercial lime	weighed	17.38 gms.
"	crushed brick	"	21.13 "
"	clean sand	"	21.70 "
"	Portland cement	"	19.30 "

BOOK REVIEWS.

The Chemical Analysis of Iron. A complete account of all the best known methods for the analysis of iron, steel, pig-iron, iron ore, limestone, slag, clay, sand, coal, coke, and furnace or producer gases. By ALEXANDER A. BLAIR. Third Edition. Philadelphia, J. B. Lippincott Co. 1896.

Many thoughts suggest themselves on the appearance of the third edition of this book. Many men, not yet reckoning themselves as "old" can remember the times when a chemist attached to a manufacturing establishment (metallurgical or other) was regarded as an ornamental and useless appendage. Sharp competition, and the consequent necessity for striving for the best attainable quality in their main products, and a possible utilization of by products, has completely changed that condition of affairs.

The consequence also has been that students of the science of chemistry have become more practical in their work and their way of regarding its bearings. Specialization in different lines, has inevitably followed. Rapid and accurate work in the analytical laboratory, to control the work of the manufactory, and to guide the buyer or seller, has become indispensable.

Special books, dealing with chemical work pertaining to particular industries have become a necessity; but each has had to submit to the critical examination of expert workers, many of whom have had a wide experience.

This is especially true in connection with one of the most important industries of our country—that of iron and steel, and the fact that a third edition of Mr. Blair's excellent book has so soon been rendered necessary, is strong testimony as to its value, and the estimation in which it is held.

The changes which have been made from the previous edition are indications of the progress made in this branch of chemistry and of the careful attention paid to them by the author. Some of the fruits of the labors of the International Standards Committee are presented in the description of the volumetric method for phosphorus, which, as stated in the preface, is tentative and not official. The changes in the manipulation of that process (which still follows the lines of Emmerton's method) are the most radical of any to be observed in the book. The molybdate reagent is made up a little stronger than before and containing much less ammonium nitrate, a plan which conduces to the maintenance of the strength of the reagent by avoiding the slow deposition of molybdic acid. Purification of the reagent (chiefly from silica) by addition of a small amount of microcosmic salt, settling and decanting off is recommended. The description of the simplified form of "reductor" is most welcome. When managed in accordance with the minute directions given, it is quite as efficient as the more elaborate form of apparatus originally described by Jones. Jones's description, and the figure of his apparatus as originally described, is retained in the chapter on iron ores, though supplemented with a suggestion as to the use of the simplified form. The use of *amalgamated* zinc in the reductor is another change. The reduc-

tion attained by this means is given as to $Mo_{24}O_{37}$ instead of as before to $Mo_{12}O_{19}$, which has necessitated a slight change in the factor by which the iron standard of the permanganate solution must be multiplied to give the phosphorus standard. In Emmerton's description the factor was $0.9076 \times 0.01794 = 0.01683$; in the improved method the factor becomes $0.88163 \times 0.01794 = 0.015816$; when the solution is boiled in a flask with granulated zinc it is $0.585714 \times 0.01794 = 0.015377$. In this connection it is noted that the change in the color of the reduced solution from green to "brown" ("port wine," according to Emmerton,) is fatal to the accuracy of the determination.

As regards sulphur determinations in manufactured irons it is remarked that no method is perfectly satisfactory. *A priori* it might seem that the sulphur determination would be the simplest determination, and the one most easily and rapidly executed, but the wide disagreement in results (when sulphur is small in amount) between different skilled analysts on the same sample, indicates that methods giving satisfactory results are yet to be desired. The objections to the evolution methods for pig irons, raised by Phillips and Matthewman are quoted; nevertheless, the author states that in steels he has always obtained what he believes to be correct results by an evolution method where evolution occurs in an atmosphere of hydrogen, and alkaline lead nitrate is the absorbent. The method which he has used is minutely described. Several modifications have been made in the description given in the former edition. One of the most important is the speed with which the operation should be conducted.

Under determinations of total carbon we have as new, Bourgeois' combustion with potassium bisulphate (applicable to ferrochrome and similar special products) and Wiborgs' method as modified by Nolly—(oxidation of the borings by a mixture of sulphuric, chromic and phosphoric acids, the CO_2 being measured). The descriptions of one or two methods which are now but seldom used, have been omitted.

The method for the separation of arsenic in irons by precipitation has been dropped out, that by distillation being retained.

A rapid method for determination of tungsten has also been introduced.

For manganese in iron ores we find additions in descriptions of a modification of Volhard's method and that of Pattinson.

Throughout the book are also to be found new hints and suggestions drawn from recent chemical literature, indicating the care with which every detail of the directions of the former edition has been scrutinized.

The book merits, and cannot but receive, a most cordial welcome.

E. W.

A Manual of Quantitative Chemical Analysis for the Use of Students. By FREDERICK A. CAIRNS, A.M. Revised and Enlarged by Elwyn Waller, Ph.D. Henry Holt & Co., N. Y. 1896. Octavo, 417 pages. Price, $2.00.

This manual is admirably adapted to the needs of students pursuing a course in mineral or inorganic quantitative analysis and at the same time is a handy reference book for chemists of experience.

The general arrangement of the first edition is preserved, except that the chapters on commercial organic analysis, such as soap, oil, calcium acetate, etc., have been omitted. The author first gives instructions as

to measuring, weighing and other operations, also precautions in regard to the use of platinum and directions for preparing reagents; then methods for the analysis of pure salts, such as barium chloride, magnesium sulphate, calcium carbonate, etc.

The main portion of the work consists of twenty-nine chapters devoted to the following analyses: Feldspar, Limestone, Clay, Manganese Ore, Iron Ores (partial and complete analysis), Chromite, Slags, Manufactured Irons, Aluminum, Zinc Ore, Nickel Ore, Copper Ore, German Silver, etc., Lead Ores, Tin Ore, Bronze, Arsenic Ore, Antimony Ore, Type Metal, Refined Lead, Paint, Water, Acidimetry and Alkalimetry, Soda, Chlorimetry, Fertilizers, Coal and Nitrates.

The appendix contains besides tables of specific gravity of acids, alkalies, etc. Dr. Waller's "Properties of Precipitates," which shows the student at a glance the solubility, best conditons for formation and possible contaminants of any precipitate he is likely to use.

The improvements in certain chapters deserve special mention. The analysis of iron ore has been largely rewritten and new features introduced, also schemes for the separate determination of iron, sulphur, phosphorus and silica. The chapter on manufactured iron (35 pages) has been revised and contains the volumetric method for phosphorus by titrating the "yellow precipitate" after reduction by potassium permanganate. Dr. Waller has adhered to the old ratios in this case giving the composition of the precipitate as $12MoO_3$, $(NH_4)_3Po_4$ and the oxide formed after reduction as $Mo_{12}O_{19}$. In spite of the great discussion of these reactions, opinion differs in regard to them but the preponderance of testimony is against the old Emmerton ratio as given in this book. The other methods described are excellent.

A new chapter, devoted to aluminum and aluminum bronze, is a valuable addition. Under copper ore, the "cyanide" and "iodide" methods now largely used are described. Under arsenic, Pearce's method and the distillation method are described in full. Nearly fifty pages, devoted to the analysis of fresh and mineral waters are especially valuable on account of Dr. Waller's great experience in this work.

The revised book has been prepared with great care and in its superiority over the previous edition keeps pace with the rapid advance of analytical chemistry during recent years. E. H. M.

Elementary Solid Geometry and Mensuration. By HENRY DALLAS THOMPSON, D.Sc., Ph.D., Professor of Mathematics in Princeton University. New York, The Macmillan Company, 1896. 200 pp, Price, $1.25.

This is an exceedingly elementary work on geometry, brief and interesting, well conceived and well written. In it the author has endeavored with much success to build up a logical train of reasoning, as compact as possible, and at the same time to impress upon the pupil the fact that the acquisition of an exact mode of expression is one of the most valuable results of the study of geometry. J. W. D.

Trigonometry for Beginners. By the REV. J. B. LOCK, M.A., Fellow of Gonville and Cains College, Cambridge. Revised and enlarged for the use of American schools by John A. Miller, A. M., Assistant Professor of Mathematics, Leland Stanford Jr. University. New

York, The Macmillan Company, 1896. 147 pp., and 63 pp. of tables. Price, $1.10.

This is a most excellent book for beginners. It is a good-sized octavo, upon whose roomy pages the text, formulæ, diagrams and tables are disposed in a pleasing way. The paper is unusually thick, and the print unusually bold, sharp and clear, which makes the appearance agreeably substantial, and invites perusal.

The subject itself is elucidated in a remarkably clear, easy and thorough manner; all the essential propositions are contained, and nothing superfluous. Abundant exercises in proving trigonometric identities follow each group of newly derived formulæ. A special chapter is devoted to the solution of trigonometric equations, a topic omitted in too many treatises; and another chapter familiarizes the student with the use and notation of inverse trigonometric functions. The question of ambiguity of solution has received careful attention.

The tables are computed to five places of decimals, and were arranged by Dr. Frank L. Sevenoak of the Academic Department of Stevens Institute. The explanations preceding the tables are exceedingly concise and clear. It would be hard to praise this book too highly.

J. W. D.

The Elements of Physics; Vol. II., Electricity and Magnetism. By EDWARD L. NICHOLS and WILLIAM S. FRANKLIN. New York, The Macmillan Company. 272 pp., 228 diagrams and illustrations. Price, $1.50.

The second volume of the series of three on *The Elements of Physics*, by the above authors, has just made its appearance. The work is intended as a college text-book and proves by its contents and mathematical treatment, that it is thoroughly up to date. The opening chapter on "Distributed Quantity," sets forth a few fundamental theorems in regard to scalar and vector quantities. In mastering this portion of the book the student acquires sufficient mathematical knowledge to easily follow the remainder. The next three chapters are devoted to the ordinary discussions of permanent magnetism, galvanometers, resistance and electromotive force.

Under "The Electric Charge" the authors present the theory of the ballistic galvanometer for measuring transient currents, followed by an admirable treatment of the theory of electrolysis. Simple electrical measurements form the topics of a separate chapter.

From this point on the authors confine themselves for seventy pages to "Electrostatics," which they present under four heads: First, the ordinary simple phenomena; second, a mathematical investigation of the properties of the electrostatic field; third, "Capacity," and fourth, the phenomena of discharge, among which Röntgen rays are mentioned.

The next subject considered and treated in a very able manner is Magnetism, including among other topics Magnetic Flux, Magnetizing Force, Susceptibility, Permeability, Hysteresis and Diamagnetism.

This subject being disposed of brings the student to questions of induced electromotive force, self and mutual induction. Thermo-electricity is touched upon, followed by a curious chapter of only eighteen pages devoted to the practical applications of electricity and magnetism, in which the authors attempt to explain the various methods and apparatus in so brief

a manner that unless very much amplified by lectures, this portion of the book would be of no service whatever to the ordinary college student.

The volume closes with two very useful chapters; one, a résumé of electric and magnetic equations, arranged so as to point out the similarities and points of difference between them; the other, explaining the mechanical conceptions of electricity and magnetism.

A . a whole, the volume is most certainly a valuable aid to the student on account of the unusual clearness of its deductions aided by especially fine diagrams. It will, without doubt, be given a high rank among the mathematical text-books on physics. W. H. F.

Röntgen Rays and Phenomenon of the Anode and Cathode. By Edward P. Thompson. D. Van Nostrand. 1896. 190 pages. Octavo.

The wide-spread interest, both scientific and popular, in the subject of radiant energy developed within and from a discharged tube as a source of X-rays forms the topic of this book. The author aims to interest the student and those generally interested in science, and in this attempt he introduces the method, which is so convenient for reference, of numbering the paragraphs so that cross-references can be rapidly and conveniently made. The surgical bearing of the X-ray is a very wide field of its interest and receives considerable reference. The photographic side also, for professionals and amateurs, is considerably treated. The author protects himself in its Preface against the very critical difficulty in a subject which has been developing so rapidly, lest in his accrediting of an experiment or discovery he shall have disappointed some who may have antidated the published experiment.

The Introduction gives its definition of the Röntgen and X-ray as a form of energy radiated from a highly exhausted discharge tube, which is energized by an induction coil or other suitable electrical apparatus. While the book does not entirely follow the chronological method it outlines the early experimentation with brush discharges by Faraday and others, and the Maxwell Plücker and Geissler investigations which have been so thoroughly identified with physical apparatus in use for many years. Later the test figures identified with the names of Lichtenberg, Hammer and McKay, and the early Tesla experiments. Then follows the investigations on the cathode rays followed by Lenard up to which the history is led to the time of the Röntgen experiments in January, 1895, and the latter developments by Edison and the host of other experimenters whom the Röntgen announcement has stimulated to wide research.

The book is very copiously illustrated, and modern contributions receive a personal interest by cuts of apparatus and figures, as well as reproductions of some of the best work.

The final chapter, by Prof. William A. Anthony, covers the résumé of the theoretical relations which seem to be suggested by the state of the art at the time of writing. The book is preceded by a portrait of Dr. William Conrad Röntgen in half tone, which process is also used for most of the sciagraphs with which the book is illustrated. There are sixty diagrams.

It represents an enormous amount of work in investigation, collocation and cross reference, and will be found very useful and complete to any one to whom this subject may come to be taken up in detail. F. R. H.

Humphrey Davy, Poet and Philosopher. By T. E. THORPE, LL.D. F.R.S. The Macmillan Co. 1896.

It is a little difficult for the scientist of the present day to put himself back into the conditions which prevailed in England with respect to such matters in the beginning of the present century. For this reason the biography of two hundred and thirty-six pages which introduces Davy as a scientist, and the influence which the Royal Institution of Great Britain has had in offering an arena for some and an asylum for others of those who have helped to bring the abstractions of science to the service of all, is a book which may well receive more than passing notice. The Royal Institution was an establishment as originally conceived for the benefit of the poor, and it was deemed expedient in that day when the influence of purely altruistic motives was less thought of, that it was desirable to render it fashionable to coöperate in the work of such an organization. Count Rumford was an enthusiast for philanthropy in the direction of procuring comforts and conveniences of life through the improvements of arts and manufactures due to science, and aimed to have this attained by effusing knowledge and full philosophical lectures and experiments. It was in 1802 that Davy, summoned from Bristol some months before, began his first lecture which marked and stamped upon the Royal Institution the character which it has since retained and which up to that time it had been scarcely able to acquire. From that time on its laboratories became the centres of much of the deductive experiments in chemistry and electricity in the first decade of the century. It would be impossible to make details of reference to Davy on the work in his relation as head of the laboratory, but the alkalis and alkaline earths, the discovery of chlorine, fluorine, and his investigations on carbon in form of the diamond are but a few of those which from 1803 until his health failed in 1824 emanated from the laboratories of the institution.

In 1813 Michael Faraday entered the laboratory as assistant to Sir Humphrey, and from that time on they worked in coöperation and in close friendship.

So much of the early chemical work of those days has been built into the foundations of modern science in connection with the contemporary and later work of others, that it is sometimes hard to disentangle the work of any one from that of all, but the name of Sir Humphrey Davy is intimately associated in the minds of all engineers with the service which he rendered among the fiery mines of Great Britian by the invention of the Davy safety lamp. The collieries of the North of England have been greatly stimulated by the developments of the iron business after puddling had been introduced, and by the improvements in the steam engine which had occasioned a much more wide spread application of machinery to industry. In the early days of working in such mines the shafts were shallow and the workings usually but a short distance from the shafts. These were conditions which enable primitive methods of ventilation to be satisfactory, although the explosions from the use of naked lamps had not been unknown under the earlier conditions. Ventilation by furnace was introduced in England in 1732, and attempts to light by the flow of sparks from steel and flint had been attempts to avoid the use of flame light. By 1812 explosions had begun to become frequent and had caused a loss of life which had directed public attention to the dangers of the miners, and a society was formed to investigate and seek for

remedies. It was in that year that Davy was asked to give attention to the subject, and after some exhaustive experiments he discovered the principle that explosive mixtures of fire damp will not pass through small apertures and tubes, and it was on November 9th of that year that his first paper was read before the Royal Society. Its "Philosophical Transactions" contains illustrations of the first and later safety lamp, and are reproduced in Mr. Thorpe's book. The lamp was immediately widely introduced, and recognition poured in upon Davy from all sides in the form of addresses, public meetings, banquets, sets of plate, and the like. He was urged by several of his friends to protect his invention by a patent. They suggested to him that its value would be represented by five or ten thousand pounds a year, but his letter to one of these friends contains the following paragraph:

"My sole object was to serve the cause of humanity, and if I have succeeded I am amply rewarded in the gratifying reflection of having done so. More wealth would not increase either my fame or my happiness. It might undoubtedly enable me to put four horses to my carriage, but what would it avail me to have it said that Sir Humphrey drives his carriage and four."

Mr. George Stephenson had also been working on very much the same lines, and as is so often the case the two men reached the same result by independent investigation. Davy's solution, however, seems to have been the more elegant of the two and to have been a direct deduction from scientific principles. He received the Rumford medal of the Royal Society in 1816 for his work in connection with flame and the lamp. Realizing what such a laboratory as that conducted by the Royal Institution had done for science it was his desire that similar laboratories should be maintained and administered, but he received no effectual support.

There is much of interesting personal reminiscence and suggestion in the book concerning the fishing trips which Davy took and his friendship for Sir Walter Scott. One who was present at an evening talk of Scott and Davy is reported to have said, "This has been a very superior occasion; Sirs I wonder if Shakespeare and Bacon ever met to screw each other up."

His health failed in 1824 and he crossed to the continent for travel in warmer climates, experiencing benefit for a time, but he was never entirely well thereafter. His death took place in Geneva, May, 28, 1829, and his monument is in that city. F. R. H.

A Preliminary Report on the Clays and Clay Industries of the Coal and Coal-bearing Counties of Indiana. By W. S. BLATCHLEY. 20th Ann. Rept. Dep't. of Geology and Natural Resources. Pp. 23–184.

It is extremely gratifying to see one more State recognize the importance of its clay resources, and especially Indiana whose plastic materials are of such importance. The present report includes the counties of Parke, Fountain, Vermilion, Vigo, Clay, Owen, Greene, Sullivan, Knox, Daviess, Martin, Dubois, Pike, Gibson, Vanderburgh, Warrick, Spencer, Perry and Lawrence.

After a brief introduction on the nature and classification of clays, the deposits are described by counties. Most of the beds are interstratified

with coal, sandstone and shale, and they are often of excellent quality. Many sections are given as well as numerous analyses.

The recent nature of the information about the Indianaite or kaolin of Lawrence Co., is interesting. According to Mr. Blatchley the deposits of this material have not been worked since 1892, and prior to that date was only used for sizing paper.

The description of the clay deposits is followed by a brief account of the methods of manufacture.

The clay products produced in Indiana together with their annual value are:

Paving brick,	$310,000
Common brick and drain tile,	291,510
Dry pressed brick,	160,000
Earthenware and stoneware,	29,100
Sewer pipe and hollow goods,	340,000
Firebrick,	3,050
Total,	$1,133,660

H. R.

DEPARTMENT NOTES.

METALLURGICAL DEPARTMENT.

A new feature in the course of instruction in metallurgy was inaugurated this year. A Summer School in Practical Metallurgy was held at Butte, Montana, in July, at the expiration of the time devoted to the Mining School.

The class of students under the direct supervision of Dr. Struthers took up the study of the smelting of copper and silver ores at Butte, Mont. This district afforded an excellent field, as Montana produces over one-half of the United States' supply and over one-fourth of the world's supply of copper. Montana's production for 1895 was over 180,000,000 pounds of copper and over $20,000,000 of silver.

The requirements were strictly adhered to and comprised all the important data relative to the subject, including the description of process as employed at the special works visited, sketches of furnaces with dimensions, calling for plans, sections, elevations and special drawings, the chemistry of the processes, the mechanical handling of material, labor, costs, etc.

Class and individual instruction were given by Dr. Struthers. Note books were freely used and were corrected and criticized before the following day's work, while the subject was fresh in mind.

All the smelting and refining works at Butte were visited and studied, and the mammoth plant at Anaconda, which treats four thousand tons of ore daily, was also visited, including the large electrolytic department where the gold and silver contents of the copper are electrolytically separated and the copper purified.

This year the summer school was optional and it is gratifying to note the full attendance of the students and the excellent quality of their work.

It is to be hoped that this important factor in the instruction of metallurgy will be made permanent. Metallurgy is an eminently practical subject, and the lectures should be supplemented by practical work of this character in order that the student should possess a rounded knowledge of the subject. It is as important for the instruction in metallurgy as a dissecting room is in the study of anatomy.

Dr. Struthers extended his trip through all the important smelting works in the West and in British Columbia, spending over three months in visiting more than forty establishments, securing many new drawings and facts for the benefit of the Department. Many valuable specimens illustrating the various processes were also gathered for the metallurgical collection.

From the following list may be seen the severity of the requirements:

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK. SCHOOL OF MINES.

SUMMER SCHOOL IN PRACTICAL METALLURGY, 1896.

Scheme of Study: The smelting of copper ores at Butte City, Montana.

A. Ore Roasting.

1. *Stall Roasting.* Construction. Kind of brick and how bound. Make sketch showing arrangement in group and give height, width and depth; describe flues for admitting air to stall and removing gases to chimney. Working. How filled; size of ore; fuel used; total capacity; time of roasting; composition of ore before and after roasting; cost per ton.

2. *Furnace Roasting.* (*a*) Single hearth. Construction. Kind of brick and how built; sketch plan of hearth, showing doors and fire place. Dimensions required. Fire-place and hearth. Working. How charged; how moved through furnace; how discharged; sulphur contents of ore before and after roasting; fuel used; cost per ton.

(*b*) *Mechanical Furnaces. The Kellar Furnace.* Construction. Kind of brick and how built. Sketch transverse and longitudinal sections; detailed sketch of rabbles and plows; describe fire-places; demechanism for moving rabbles, power required. Dimensions required. Exterior length, width and height. Interior length, width and height of hearth and width of slot; total hearth area. Describe the manner of closing slots and ends of hearth; time of rabble passage and power required. Working. How charged; how moved through furnace, how discharged; thickness of ore on hearth; sulphur contents of ore before and after roasting; fuel used; capacity per day; cost per ton; total cost of furnace.

(*c*) *The Wethey Furnace.* As above.

(*d*) *The Allen O'Harra Furnace.* As above, substituting detailed sketch of chain and plows for the rabble and slots.

(*e*) *The Pearce Turret Furnace. Single.* Construction; outline sketch showing general design; give plan of hearth; sketch of fire-place,

showing ash pit, grate bars and curtain arch; mechanism for passing material through furnace. Best shown by section of hearth and plan of rotating arms; detailed sketch of arms and plows. Dimensions required. Total diameter; diameter inside space; interior width and height of hearth, fire-place and hopper; discharge opening for roasted material. Describe dust chamber, flue and chimney. State kind of brick used and how bound. Working. Composition and size of ore treated; describe charging; passage through furnace; discharging; air introduction to hearth and fire-place. Ascertain furnace capacity per 24 hours; fuel consumption; amount of sulphur before and after roasting; time of arm rotation; power required for same; labor; cost per ton under conditions existing here; repairs; total cost of furnace construction.

(*f.*) *Pearce Turret Furnace. Double.* As above with detailed detailed description of 2d hearth and arrangements of hearths and fire-places.

(*g.*) *Circular Calciners.* How constructed and of what material. Give vertical section, showing hearths; detailed sketch of revolving arms. Dimensions. Exterior, diameter and height, interior, width and height of hearth. Working. Describe charging, passage of material through furnace and discharging. Ascertain composition of ore before and after treatment, cost per ton, total cost of furnace. (Note no fuel used).

B. Smelting for Matte.

1. *Shaft Furnace.* Describe construction; make transverse section, showing interior shape, water jackets and tuyeres. Detailed description of fore-hearth. Ascertain number and size of tuyeres; pressure of blast. Dimensions required. External length, width and height of hearth, water jackets and shaft. Internal section at tuyeres and at charging floor; height of charge from tuyere to top; depth of molten material in furnace; give details of four-hearth and slag pots. Working. Composition and size of ore, flux, fuel. Composition of slag and matte. Describe charging, removal of slag and matte. Enquire capacity per 24 hours under stated conditions; labor; cost per ton of matte produced.

2. *Reverberatory Furnace.* Construction. Make horizontal and vertical sections; sketch end elevation, showing flue and chimney; kind brick used and how held together; composition of hearth; if air is preheated describe method. Working. Composition of material treated, how charged; composition of slag and matte, how removed from furnace; kind of fuel used; amount per ton of matte produced; labor. Enquire capacity per 24 hours and cost per ton of matte produced under stated conditions; total cost of furnace.

C. Treatment of Matte.

Bessemerizing Copper Matte. Construction. Make sketch showing method of construction and how rotated; details of stand, top, centre and bottom shell; how held together; describe wind box, tuyeres and plugs, lining. Working. Composition of matte treated and product; how charged; skimmed and discharged; pressure and amount of blast; length of blow; capacity under stated conditions; cost per ton of matte treated.

JOSEPH STRUTHERS, Ph. D.,
Butte, Montana, *July 11, 1896.*

MINERALOGICAL DEPARTMENT.

RESIGNATION OF PROF. EGLESTON.—Dr. Egleston, the founder of the School of Mines and head of this Department for thirty-three years, has resigned on account of ill health and has been made Professor Emeritus. The resignation takes effect June 30, 1897. His successors have not been appointed.

MINERALOGY IN THE COLLEGE.—The five undergraduate courses in this department have been made electives in the new curriculum of the College and the Faculty of the College has also approved at their meeting of October 23d, the following course in General Mineralogy designed as an introductory course to mineralogical work under the Faculty of Pure Science and replacing, for this purpose the special technical courses hitherto made prerequisites:

General Mineralogy.—First term: definitions, principles and laws, crystal forms, appearance and properties of common minerals, practical determination of minerals. Second term: physical properties of crystalline substances with practice in elementary determination of physical constants and measurement and delineation of geometric form.

UNIVERSITY COURSES.—In order to secure a series of university courses which can be based upon this course as a foundation. Courses VII., VIII., IX. and X. have been rearranged as follows:

VII. (Especially a minor course for geologists.)

OPTICAL MINERALOGY.—Longer course, including principles, apparatus and distinguishing characters of minerals in sections, determination of optical constants, study of microstructure, microchemical tests, separation of constituents and preparation of sections.

VIII. (Especially a minor course for chemists.)

PHYSICAL CRYSTALLOGRAPHY.—Optical, thermal, electric and magnetic properties of crystals with experiments, the geometric form with measurement and delineation, the effects of mechanical forces, theories of structure.

IX. (Major course for mineralogists.)

PHYSICAL CRYSTALLOGRAPHY.—Longer course, including study of the crystals of some isomorphous group, the artificial preparation of the crystals and their physical and chemical properties.

X. MINERALOGY.—(Major course for mineralogists.)
Study of assigned group or species.

ARRANGEMENTS AT THE NEW SITE.—The collection will occupy a room 50′ x 75′ with a narrow gallery on one side. This will permit an expansion of about ten cases. There are several directions in which, by judicious selection, the specimens illustrating a certain phase, may be brought together and made more valuable. The purely systematic collection, arranged by composition and crystalline form, is always essential for the study of the individual species and their relations to each other. Such a collection will, almost universally be arranged in order of the acid constituent, and with fairly constant proportionate allotment of space. For instance, the systematic mineralogical collections of South Kensington museum, Berlin museum and Vienna museum are ar-

ranged in nearly the same order and the space allotted is proportioned approximately as follows:

	South Kensington.	Berlin.	Vienna.	Approx. Average.
Native elements	5	5	5	5
Compounds of Metals with Arsenic and Sulphur Groups	12½	15	18	15
Compounds of Metals with Chlorine group	4½	5	6	5
Silica	7½	5	4	5½
Other Oxides, Hydroxides and Hydrates	11½	11	9	10½
Carbonates	12½	9½	14	12
Silicates	28	35	19	27
Sulphates, etc.	5	5	9	6
Chromates, Molybdates, etc.	2½	2		2
Phosphates, Arsenates, etc.	8½	7	10	8½
Organic			2	2
Sundries	2½	0½	4	1½
	100	100	100	100

But collections arranged with some other end in view are also greatly needed. In our own department nearly half of the collection is arranged to bring the ores of the same metal together, and small special collections have been developed as pseudomorphs, characters of minerals, crystals, etc. Under characters of minerals may well be included not only form, structure and physical properties, but paragenesis, as illustrated by inclusions, parallel growths, secondary growths, etc., and chemical properties, as illustrated by isomorphism, dimorphism, etching, solubility, pseudomorphism, decomposition, etc.

There may be also technical collections of mining products, raw material for chemical industries, precious and ornamental stones, collections of laboratory crystals and synthetically prepared minerals.

Directly under the collection room is another room of equal size, which to keep as brightly illuminated as possible will be considered to constitute three rooms practically without partitions. The mineralogical and blowpipe laboratories, which have hitherto been combined to the great detriment of mineralogical work, will be separated. The lecture room and the mineralogical laboratory will be in one, with suitable desks, facing the professor's pulpit, supplied with streak plates, hardness scales, etc., while at the windows there will be hand-blast blowpipes, blowpipe reagents and a large hood for testing solubilities. Student and lecture collections will be in this room also.

The blowpipe laboratory will be the southeastern end of the room, and will not differ from the present room materially. It is hoped that all or part of the apparatus hereafter may belong to the department and be loaned to the students. A small room will be partitioned off as a laboratory for analytical and synthetical researches.

On the first floor a large, light annular space under the great lecture room will be fitted for microscopic work. Two dark rooms on the basement mazzanine floor will be divided by curtains into small rooms for goniometrical work, work with monochromatic light and photography.

A small room in the basement will contain the saws and grinders for preparation of thin sections and the cutters and breakers used in preparation of material for collection.

A large room has been set aside as office and library, and it is proposed to transfer to the department all periodicals, monographs and special works on mineralogy and crystallography from the University Library, with such current text-books as are desired. The large card catalogue is being pushed to completion and now comprises nearly 20,000 cards.

IMPROVED EQUIPMENT. — The equipment is being expanded as rapidly as funds will permit. Many of the latest forms of apparatus* have been added this year, including:

No. VI. Fuess Microscope with simultaneously rotating nicols.

Six Seibert lithological microscopes II A.

Klein's universal rotation apparatus for crystals, especially for determination of optical principal sections and measurement of angles between optic axes in liquids of high index of refraction.

Klein's universal rotation apparatus for thin sections, especially for exact orientation of haphazard sections and determination of their optical constants.

Traube's apparatus for darkening field of goniometer.

Laspeyere's burner for monochromatic light. Lamp for goniometer.

Attachment for converting Fuess goniometer into an axial apparatus.

Attachment for deliquescent crystals Fuess goniometer.

Von Federow Mica wedges for measuring strength of double refraction.

Models of positive and negative uniaxial indicatrices and of the biaxial indicatrix with sections normal and oblique to optic axes.

Apparatus for electrical heating on stage of microscope.

Total reflectometer.

Photographic camera for microscope.

Other orders are outstanding which will make the equipment still more complete.

MICROCHEMICAL TESTS.—To illustrate the microchemical tests commonly used on thin sections in contradistinction to the innumerable tests on record, a small series has been prepared in which each section has been cut in two, one-half being treated, the other kept unaltered. The methods employed are principally confined to the effect of heat in browning certain minerals containing iron or carbonaceous material, and reactions with hydrofluoric acid on silicates, either in producing crystals of some definite compound or in the production of a jelly.

The cover glasses were removed by warming, their surfaces washed with a mixture of alcohol and benzole; a cut is made with a diamond on the section, then heat applied and the desired portion lifted and dropped into benzole and alcohol, from which it is removed to platinum foil or balsamed glass, submitted to treatment, replaced on an object glass with very dilute balsam and covered.

The series is as follows:

1, 2. *Hornblende Schist of Militz, Saxony.* By heating on platinum foil without blowpipe the green hornblende is made brown.

3, 4. *Leucitophyre of Rieden, Laach.* By heating with blowpipe the green augite is made brown.

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* Described *N. Y. Acad. Science.*

5, 6. *Basalt of Braunrode, Meissen.* By heating without blowpipe the augite is unchanged, the olivine is made nearly black.

7, 8. *Serpentine of Rauhenthal, Alsace.* By heating without blowpipe the serpentine is little altered, retaining its aggregate polarization.

9, 10. *Diabase of Freseburg, Hartz.* By heating without blowpipe the chlorite is much browned.

11, 12. *Dichroite Gneiss of Bodenmais, Bavaria.* Heated with blowpipe the dichroite in the section did not alter, but a fragment so heated became blue or greenish.

Phonolite of Bruxer, Schlossberg. Treated for 3 hours in dilute (1–10) HCl, then much diluted and left 36 hours, then repeatedly washed and treated with very dilute fuchsin a jelly formed on nephelite which was colored by the fuchsin.

14. *Nephelite grain* placed on glass which has been completely covered with Canada balsam to prevent acid attacking glass treated with drop of HFl and the resultant crystals twice recrystallized in drop of water, gave short hexagonal columns of sodium silicofluoride.

15. *Chrysolite grain* similarly treated gave rhombohedra of magnesium silicofluoride with strong double refraction.

16. *Plagioclase grain* gave long pointed crystals and rosettes of the calcium salt.

17. *Granite of Baveno, Lake Maggiore,* treated with HFl, then with fuchsin should have shown most color on plagioclase, less on orthoclase, none on quartz. The results were not good.

18, 19. *Phonolite of Plären,* containing colorless unaltered Haüynite and nosite, heated the haüynite became blue, the nosite remained colorless. This test will not work if the minerals are decomposed.

20. *Phonolite of Plären.* Treated with Lemburg's solution (HFl + $AgNO_3$) the haüynite became brown.

Graphitoid vs. Graphite, the powder of the former becomes white by heat, that of the latter remains black.

PUBLICATIONS.—The series of text-books on Mineralogy is being completed, the second edition of the Mineralogy by Profs. Moses and Parsons is now being printed and a supplementary work entitled "An Introduction to the Study of the Characters of Crystals" is in preparation. Dr. Luquer is also making progress with his book upon optical mineralogy for students which deals more with the phenomena as exhibited in thin sections.

GEOLOGICAL DEPARTMENT.

Professor Kemp left on May 28 with the class of the regular Summer School in Mining and Geology, and made the first stop at Niagara Falls and Lockport. Two days and a-half were passed in studying the Silurian exposures at these places and the overlying Devonian in the outskirts of Buffalo. Beginning at Lockport, the class passed from the upper beds of the Niagara limestones on the Erie Canal downward across the Niagara shales and Clinton limestones and shales to the Medina sandstones, which are well exposed in the local quarries. At Niagara a trip was made to Lewiston by cars, and a return journey on foot through the gorge, so as to observe the same succession of strata as at Lockport, and to study the wonderful exhibition of erosion afforded by the gorge. The problem

of the development of its drainage was set forth on the banks of the Whirlpool, so that the class could understand the scientific and popular interest that attaches to Niagara as a measure of the time that has elapsed since the Glacial period. At Buffalo the cement quarries in the northern part of the city were visited and observation was directed to the Waterlme beds and the Corniferous limestone.

The class then boarded the train for Chicago, where a part of the next day was passed in visiting the lime and building stone quarries of that city, which expose the same Niagara limestone that had been previously seen in New York State. Again boarding the cars a ride of two nights and a day brought the party across Illinois, Iowa, Nebraska and about two-thirds of Wyoming, until Point of Rocks was reached. Here at 6:30 one morning all alighted for a trip into the Bad Lands to the Leucite Hills, a remarkable series of lava flows and low cones that have afforded rare rocks containing the interesting minerals which give the hills their name. Unfortunately, the available maps indicated a nearer location to the station than the actual geography warranted. A spring, too, that is recorded on the map proved so far in the wilderness that it was not even seen. The class had a fine opportunity to observe the Laramie strata and the characteristic topography and geology of the Bad Lands. After a hard and inordinately thirsty trip, Prof. Kemp and four of the class reached the lava flow, secured specimens and tramped back after the others who had previously returned. No serious results accrued and the trip passed into history as one of the finest to remember that the party had ever experienced.

Resuming the journey by an evening train, the next day brought the class to Butte. The following morning the class ascended the rhyolite butte and walked along the outcrops on which are located the principal belts of mines. Observation was directed to the granites, rhyolites and local mineralogy of the veins. The second day the tramp was to the south along the railways to the Bluebird mine. The basic and acid granites were found well exposed and their relations were studied. Returning, various silver mines were visited, including the Alice, the Moulton, the Lexington and others without going underground. The third day the class tramped to the bordering hills to the north, studying the gossan of the undeveloped veins and the remarkably weathered granite, and visiting a small placer workings. The fourth and final day of geological work was passed in a trip to the east, to the new developments that are testing the eastern extension of the lodes, thence through the Great Northern tunnel and over two divides to Columbia Gardens, from which all returned to Butte and the geological work closed. Thanks are due to Mr. W D. Thornton, who piloted the party around and who contributed in a very essential way to the success of the work. The purpose of the trips, besides the acquiring of geological experience, was to give the class an idea of the local geology before the underground work was taken up by Professor Peele.

Professor Kemp with C. A. Macy, '95, went over the divides on a collecting trip into Idaho, after the geological work closed and under the guidance of H. H. Armstead, Jr., saw something of a little known portion of the State. Subsequently on the way home, the Yellowstone Park was visited, and the Black Hills, and many valuable additions were made to our collections. In the Black Hills, especial courtesies were extended by Professor F. C. Smith, of the School of Mines at Rapid City.

August and September were passed by Professor Kemp in field work in the eastern Adirondacks in the employ of the U. S. Geological Survey. During August, D. H. Newland, fellow in geology, accompanied him, and in September, John D. Irving, graduate student.

During the summer Mr. Hollick and Mr. Newland explored the serpentine area of Staten Island, for the purpose of obtaining observations and material to assist Mr. Newland in his thesis on the subject. Two minerals not before recorded from Staten Island were amongst the material collected. Valuable observations were made, which, it is hoped, may assist in the solution of the problem as to the origin of serpentine. Mr. Hollick also visited the clay marl exposure at Cliffwood, N. J., where new and interesting fossils were obtained, and made a reconnoissance of Block Island and Montauk Point, in both of which places interesting material was found. The first recorded proof of the existence of Cretaceous strata on Block Island was one of the results of the trip. Mr. Hollick has recently been appointed by the New Jersey Geological Survey, to examine and report upon the relation between geological formations and the distribution of vegetation throughout the State.

Mr. van Ingen spent a part of the month of July at Baterville, Independence County, Aakansas. The Paleozoic rocks of the vicinity were studied and large collections of fossils secured. A fauna new to Arkansas was found in the Ordovician rocks. Silurian material from St. Clair Spring and Cave Creek was obtained in abundance and a representative collection of the Devonian that occurs in the midst of the Sub-Carboniferous at Spring Creek was secured. Notes were also taken on the occurrence of the Manganese deposits and specimens to illustrate the observations were obtained. The excessive heat soon put a stop to field work fortunately after the more important work mapped out had been accomplished. The work, though of short duration, is considered to have been very profitable.

Mr. Theodore G. White, assisted by Mr. Charles Of, '96, spent August and part of September in collecting additional material for his monograph upon the Trenton Formation in the Lake Champlain Valley. The localities visited this season were as follows: Fort Frederick, N. Y. and Chimney Point, Vt., both near Port Henry, N. Y., where a section extending from the Calciferous well up into the Trenton formation was carefully surveyed and measured, and an extensive series of fossils collected from the 87 different zones distinguished. Similar work was done in regard to an extensive section on Grand Isle (South Hero) Vermont. Some time was spent in the vicinity of Plattsburgh and Beekmantown, N. Y., at Cumberland Head and Point au Roches, in order to determine the possible relations of a peculiar Trenton fauna discovered during the geological trip of 1895, and in which fossils hitherto only figured from Newfoundland were found. Chazy, N. Y., Adam's Ferry and Panton, Vt., were also visited and collections made. Altogether 12 boxes of specimens, representing probably 1,500 pounds were added to the study collections of the Upper Ordovician by Mr. White's trip. A number of dykes not recorded in either of the previous papers on the igneous rocks of the Lake Champlain Valley were discovered. One of these of especial interest was thickly brecciated with fragments of granite, hornblende, feldspar, etc. This occurs on Cumberland Head. Another from Grand Isle, in a bed of most marvelously distorted slaty limestone, had both

walls completely altered to a friable sandstone, while the centre remained quite fresh. Considerable attention was devoted to recording the directions of faulting and cleavage development, so prevalent there, in the hope of determining the relations of the several sets of cleavage and perhaps deducing a rule for them. The correlated results, however, disclose no rule applicable in all cases.

Mr. White also spent some time in western Massachusetts, and the neighboring portion of New York and Vermont. Here he prepared, and has donated to the University, a set of the Rocks of the Original Taconic System, made famous by the early writings of Emmons, and the recent monograph of Messrs. Wolff, Pumpelly and Dale.

The Department is again indebted to Dr. Heinrich Ries, '92, for valuable contributions to its collections of rocks and fossils, which were recently gathered in Colorado and New Mexico. Some excellent things have also come from a trip made by a regular collector in our employ in Utah and Wyoming.

In December the first of the Saturday evening courses of lectures at the American Museum of Natural History will be geological in their nature. The first, December 5, will be by Prof. Kemp on The Rocky Mountains. The second, December 12, will be by Dr. C. Willard Hayes, of the U. S. Geological Survey, recently geologist to the Alaska Boundary Commission, its title is The Mountains of Alaska. The third, December 19, is to be by Mr. Bailey Willis, Mines, '78, of the U. S. Geological Survey, on The Cascade Range. The fourth and last will be by Mr. Herbert M. Wilson, Mines, '82, of the U. S. Geological Survey, on the Sierra Madre of Mexico. The Department takes especial pleasure in having the University recognize in this way the good work of its graduates.

DEPARTMENT OF MINING.

The Summer School of Mining was held this year at Butte, Montana, with a class of eleven students. Adjunct-Professor Peele left New York on May 30th to make arrangements for the session, and underground work was begun June 11th.

Previous to this date, en route to Butte, and in the vicinity of the city itself, the class, under the direction of Prof. Kemp, devoted about one week to field geology.

On account of the great distance from New York, and the consequent expense to the students, the decision to go to Butte was reached only after careful consideration, but now that the work is done it is believed that no better choice could have been made. The very large output, both in tonnage and value, and the variety of mining and metallurgical operations presented for study, make the Butte district exceptionally well adapted for our purposes.

First in importance among the mines is the property of the Anaconda Copper Mining Co., producing about 4,000 tons of ore per twenty-four hours, about equaling the production of the Calumet and Hecla in tonnage, but surpassing it in value of output on account of the higher grade of the ore. Other large companies are the Boston and Montana, Parrot, Colorado Smelting and Mining Co., Butte and Boston, and Montana Ore Purchasing Co., besides which are a number of smaller concerns. While copper is the chief product of these mines, in some of them silver is asso-

ciated with the copper, the useful metals occurring in base combinations requiring an elaborate treatment in smelting, or concentration, or both. In addition to the copper-silver properties the district contains several large silver mines, producing no copper, notably the Lexington and the Alice, but owing to the low price of silver these are now worked only in a small way. The well-known Blue Bird silver mine and mill are entirely shut down. All these mines lie in a small area, of a few square miles, immediately in and around the city of Butte, which now contains about 40,000 inhabitants. They are at elevations of from 5,600 to 6,000 feet above sea level. Most of the reduction works and concentrators are close to the town, but the great works of the Anaconda Co., at which their entire product is treated, are situated at Anaconda, twenty-eight miles from Butte.

The deepest shafts of the district are at the present time down to about 1,500 feet. Nearly all of them are vertical, with two hoisting compartments, the principal exception being the main Gagnon shaft of the Colorado Smelting and Mining Co. This shaft, at which the detailed underground work of the class was done, is now down to the 1,400 level and is an incline at about 75° to the horizontal. In the Butte shafts flat ropes are almost invariably used for hoisting—a practice exceptional in the United States, outside the mines of the Comstock lode. Flat ropes are to be employed even for the new 2,200 horse-power compound hoisting engines now being installed at two of the Anaconda shafts.

The ore-bodies of the district occur in fissure veins, faulted in some of the mines in a most interesting manner. In the Rarus mine, where the class spent two days after the regular work was completed, the rather intricate vein system has been further complicated by a wide faulted zone, which, besides being faulted laterally, apparently has been subjected also to a "down-throw," which has flattened out the dip of the veins from about 80° to 40° to the horizontal. The broken and altered material included in this zone, while largely productive, has lost entirely its vein structure. Many of the copper ore-bodies are extremely thick, reaching in parts of the Anaconda property, widths of from 100 to 120 feet. In the Gagnon mine the greatest width approximates 60 feet. These conditions make necessary the use of the Nevada Square set system of timbering. Stalls are employed only in the narrow portions. Overhand stoping, worked in floors, and usually with machine drills, is practiced in all the mines.

The copper ores of commonest occurrence are chalcopyrite and copper glance. Bornite, Enargite and Tennautite are often found, though in smaller quantities, and at the Grey Rock mine occur fine specimens of the rather rare mineral, Covellite, a sulphide of copper. These, with other associated minerals afforded interesting material for study.

The mines visited by the class were, the Gagnon, Nettie, Philadelphia, Parrot, Rarus, Silver Bow, and the Anaconda and Neversweat of the Anaconda Co. In addition, every facility was allowed for the study of the surface plants, including hoists, pumps, compressors, ore-bins and the various repair shops. In the Silver Bow shaft opportunity was given to examine a fine duplex, differential Riedler pump, having a capacity of 900 gallons per minute, to a height of 1,000 feet. The usual mine surveying was done in the Nettie mine, under the direction of Mr. J. Parke Channing, whose services for this purpose were most fortunately

obtained. Each squad of students had 4 days active work on the survey. Two days were devoted to a careful study of the concentrator of the Colorado Smelting and Mining Co., which has a capacity of 450 tons per day. The plant comprises crushers, rolls, trommels, hydraulic classifiers and separators, jigs and vanners. Visits were made also to the Alice and Moulton Silver mills, the first of which only is in operation. The system employed is dry-crushing with stamps, chloridizing, roasting in White-Howell roasters, and pan-amalgamation. Finally, Dr. Struthers, of the Metallurgical Department, took charge of the class for 5 days' work in the smelting works of the district.

It should be recorded here that, at the invitation of the Butte Scientific Society, Mr. Channing delivered an interesting lecture on the occurrence, and methods of mining of the copper and iron ores of the Lake Superior region. Mr. Channing's intimate acquaintance with the Lake practice, well qualifies him to speak on the subject, and as the lecture was given near the close of the session, the members of the class who were present could profit by the comparisons drawn between the Lake and Butte methods. Another useful evening lecture, illustrated by models, was delivered before the class by Mr. C. S. Batterman, on "Mining Litigation and the relations thereto of the Mining Expert." In the course of his remarks Mr. Batterman cited at some length the technical points involved in one or two important mining suits in which he had been engaged.

The Summer School was cordially welcomed in Butte, and its work aroused much interest. All the friends of the School cannot be named here, but among those who extended special courtesy and assistance are: Messrs. C. W. Goodale, manager; Geo. B. Moulthrop, engineer, and John Hewitt, foreman of the Colorado S. and M. Co., at whose Gagnon mine a large part of the work was done; Mr. C. S. Batterman, Mining Engineer of the Rarus and other mines; Mr. Benj. Tibby, Superintendent of the Parrot, and above all Mr. W. D. Thornton, who has been a student in our Mining Department for two years past, and to whose kind coöperation and efforts much of the success of the summer's work is due.

ROBERT PEELE.

DEPARTMENT OF MECHANICAL ENGINEERING.

The Equipment and Purposes of the Mechanical Laboratories in the School of Engineering of Columbia University for the Course in Mechanical Engineering to be begun in 1897.

It is a well established fact that the material advancement of a nation is dependent largely upon the character and number of its technical schools. These schools or colleges are those in which the sciences and arts relating to the various deportments of industry are made subjects of special study in the training of their students. They are often called Engineering Schools for the reason that successful manufacturing on any large scale must be based on Engineering knowledge and skill, and must conform to the laws underlying them.

In the year 1851, at the time of the first World's Fair in London, the exhibition developed the fact that England had fallen behind relatively in the character of its exhibits and seemed to be losing her position among the manufacturing nations of the world. So much interest was excited

by this discovery that a commission was appointed to investigate as to the extent and causes of this state of affairs. This commission reported that in their opinion the English nation was actually in serious danger of losing its position as the leading manufacturing nation of the world, and that the opinion was expressed that it was due to the inattention which had been and was being given to technical education in England, as compared with the activity on the continent in this respect. It was found that in the leading continental countries of Europe large numbers of technical schools had been established and were conducted under government control and at government expense; and with the result, as shown by the exhibits from these countries, that in material advancement they were outstripping England and seriously threatening her supremacy in this respect.

Acting on this report England at once set about establishing technical schools and has since proved their marked effect upon the industrial condition of the nation.

By a well known policy of our government, whatever is done in this in this direction in our country must be done individually by citizens. It is a happy fact that this dependence has not failed us and that to-day the technical and engineering schools of America compare favorably in number and standing with any other country in the world. Their effect upon the development of natural resources of our own country has been very much more marked than is generally known. On the occasion of a meeting of one of the engineering societies in Chicago, and a visit by the members to the South Chicago Steel Works, it was noticed that all the heads of the departments were young men, and investigation developed the fact that their average age was less than thirty-two years, and that without exception they were technical school graduates.

The latter condition of affairs obtains in nearly all of our large works. So emphatically is this the fact that a young man without a technical education can scarcely get a foothold, or even if he succeeds in this, the competition against which he must contend is so great that none but those who possess the most marked natural ability can hope to succeed.

II.

The methods pursued by a successful Engineering College are to give a thorough drill in the principles of the sciences, physics, chemistry, mechanics and mathematics, and to train the hand and eye at the same time by work in the college shops, drawing-rooms and mechanical laboratories. In the shops the student uses the tools of pattern maker and machinist, and while he can scarcely be said to learn a trade, he yet learns much about the trade of such constructors, and more concerning the properties of structural material. In the drawing-room he learns to use his hands to draw, and applies the principles of design to things which are to be made. In the mechanical laboratories, he learns by actual experience the strength of materials by testing them on proper testing machines for such work, and he is taught how to operate and test steam engines and other machinery of the sort which he is likely to meet in his business. He learns here the working of the laws which he has studied from books and their application in concrete form to motors and processes, and he is encouraged to investigate new laws hitherto but dimly grasped or unknown.

The shops and mechanical laboratories add enormously to the practical value and usefulness of a modern engineering college to its community because these give to their students just the training for a useful duty in life which class room routine without them has never been able to do. The development of such laboratories and shops is therefore a wise far-seeing and useful thing to do for the community.

III.

Columbia College in the City of New York established its technical or engineering school under the name of the School of Mines in 1864, and has graduated since then over one thousand men who have been markedly successful and useful in their business and profession, and from their training and knowledge have been able to be of benefit to the community. Columbia College has recently become a University, and has begun to occupy a most impressive location on Morningside Heights from 116th to 120th Streets on the Boulevard. Generosity of leading citizens has given the University nearly two millions of dollars for splendid buildings on its new site. The W. C. Schermerhorn gift of $350,000, the Havemeyer gift of $450,000, and the Seth Low gift of $1,000,000, have been recently supplemented by the gift of C. C. Worthington of the equipment for an experimental hydraulic engineering laboratory as a memorial to his father, the late Henry R. Worthington, mechanical and hydraulic engineer.

The space at the University site to be devoted to the Mechanical Laboratories is a superb allotment of 207 feet in length and 32 feet in width, with a head-room or heigth of 20 feet. It makes an unsurpassed laboratory area, and gives a fitting and appropriate recognition to the importance of the work of the mechinical engineer in a community such as that of so great an industrial centre as Greater New York.

IV.

The detail of the laboratory equipment of a technical or mechanical engineering school covers four divisions:

I. The hydraulic laboratory has already been provided by Mr. Worthington's gift. It is to contain high and low pressure water pumps, hydraulic accumulators and motors, tanks, water-meters, gauges and similar equipment, and represents a value between $15,000 and $20,000.

II. The second division is the steam engineering and motors laboratory, which is also known as the dynamic engineering laboratory. This needs an equipment of steam engines of practicable size, to drill students in the handling and management of such machinery, and to enable them to make useful and real tests of it. An air-compressor has been already given by the Ingersoll-Sargeant Drill Company, but a Corliss cross-compound or triple machine of this sort will be a most desirable addition and is needed, together with indicators, dynamometers, calorimeters, pressure gauges and the like. Other motors should be included, and representative modes of transmitting power.

III. The third division is the Testing Laboratory, for testing the strength of iron and steel and other materials. Such a laboratory has two functions:

First, to give students of Mechanical Engineering an experience in

testing as part of their business, and to give them an experimental and practical knowledge of the strength and behavior under strain of the materials which they are to use in professional work.

For this purpose Columbia needs to supplement its present equipment by certain commercial testing machines of ordinary type, viz:

One Olsen Automatic and Autographic Testing Machine 100,000 lbs. capacity at	$1,800
One Olsen New Testing Machine, 200,000 capacity with extensions	3,000
One Olsen Torsion Machine	1,500
One Buckton-Wickstead Single-Lever Machine 200,000 lbs. capacity	3,000
One Thurston Lubricant Tester	350
One Woodbury Oil Tester	600
One Indicator Tester with Mercury column	250
Total	$10,500

Secondly, a college testing laboratory should be equipped with appliances to make tests on a larger scale than is to be expected of ordinary commercial laboratories of manufacturing establishments. It should be able to push forward into new fields, and thus to benefit the community and increase the world's stock of knowledge. Immense interests and the safety of multitudes depend upon the exact and reliable knowledge of engineers as to the properties in large masses of the materials which they use. New York has a right to expect this from the mechanical engineering laboratories for testing at the University which is to be its pride.

For this second function Columbia needs at the outset three machines.

1 Sellers-Emery horizontal tension and compression machine 300,000 lbs. capacity	$15,000
1 Henning tension and compression machine 3,000,000 lbs. capacity	40,000
1 Double plunger compression machine	3,000
	$60,000

The first of these represents the most advanced standards of accuracy and reliability, but its cost in larger sizes makes it necessary to use a different design where large straining capacity is to be sought. The linear capacities of the two latter machines will be those which are considered to be the most desirable by representative engineers in the different fields of structural engineering, and the machines will be designed to test long columns and piers, bridges, eye-bars and beams, either to destruction or for proof tests before being put to service.

It may be found convenient to locate these high power machines nearer to railway and wharf facilities than the elevated site of the University will permit. Much subsidiary apparatus should be developed in time around the fundamental appliances above set forth.

IV. The fourth division includes the shops. These are really laboratories, in which the students by actual work with the tools of pattern maker and machinist shall learn to know when work is ill or well-done

by others, and shall acquire at first hand those facts of experience and practice, which shall guide their judgment and common sense in those decisions on practical questions which involve a knowledge or skill of this sort. Such shop-laboratories for classes of forty men can be equipped with benches, lathes, planes, drills, milling machines and the like for about $15,000.

V.

If the foregoing propositions are sound, they should appeal with special force to those who may have had opportunity to observe their effect in their own business affairs. It is from such persons that coöperation is to be sought rather than from those whose field of labor has been in the more abstract professional lines or in purely financial affairs or in exchange. But to one desirous of doing a permanent and signal service to his country, in the line of its industrial and practical progress, the opportunity is a noble and a rare one.

The University would doubtless attach to a laboratory or to alcoves in it the names of those to whose generosity their equipment was due, thus making them a monument or memorial, than which none could be more useful nor more distinguished.

F. R. HUTTON.

ALUMNI AND UNIVERSITY NEWS.

REPORT OF THE ALUMNI COUNCIL.

At the meeting of the Alumni Council held October 28, 1896, the Secretary, Mr. Wm. Allen Smith, submitted his annual report, of which the following is an abstract:

On November 20, 1889, shortly before the inauguration of Dr. Low as President of Columbia College, the officers and committees of the Alumni Associations of Columbia College and of the School of Mines of Columbia College united in a dinner at the Union League Club, at which President Low was the guest of honor. From that time and continuing through 1893, the subject of a closer union of the Alumni of the two schools was frequently mentioned and was discussed in the governing boards of the two Associations. Various proposals and overtures were made, but up to the beginning of 1894 no definite result had been achieved beyond making Alumni of the School of Mines eligible to election as Associate Members of the Association of the Alumni of Columbia College. In 1892 and 1893 this subject was informally discussed in conversation by President Low, Professors J. H. Van Amringe and Frederick R. Hutton, Mr. John B. Pine, and Mr. William B. Parsons. As the result of these discussions and conversation, committees of conference on social reunions and federation were appointed early in 1894 by both Associations, and a like committee was appointed by the Association of the Alumni of the College of Physicians and Surgeons. The first meeting of the Committees of Conference, consisting of three members from each of the three Alumni Associations of Columbia College,

of the College of Physicians and Surgeons, and of the School of Mines of Columbia College, was held October 22, 1894, at the residence of Mr. Pine, at which the formation of a University Alumni Association or Council was discussed; it was resolved to call a joint meeting of the three Alumni Associations on the evening of November 16th, and a committee was appointed, consisting of one member from each Association, namely M,r. John B. Pine, Dr. Francis P. Kinnicutt, and Mr. William Allen Smith, to prepare a plan for a University Alumni Association or Council. On November 16, 1894, a joint meeting of Columbia Alumni, resident in New York and vicinity, was held in the Fine Arts Building, 215 West Fifty-seventh Street, at half past eight o'clock, p. m., at which 450 were present. The expenses of notices, supper, etc. ($611.40), were paid by the three Associations in the proportion of acceptance (590). The expense of the hall was provided for by the Trustees of the College. Addresses were made by President Low and by Professor Van Amringe, Dr. W. H. Draper and Professor Chandler. Subsequently the several committees recommended a plan for the formation of a University Alumni Council, and on June 10, 1895, an agreement was entered into between the Association of the Alumni of Columbia College, the Association of the Alumni of the College of Physicians and Surgeons, and the Alumni Association of the School of Mines of Columbia College, by which agreement "The University Alumni Council of Columbia College" was formed. On October 30th following, the first meeting of the Council was held at the Hotel Savoy, and committees were appointed to draft by-laws and to make arrangements for a joint alumni dinner. On November 12, the Council met at the residence of Professor J. H. Van Amringe, adopted by-laws, and elected the following officers: Professor J. H. Van Amringe, Chairman, and Mr. William Allen Smith, Secretary and Treasurer. On December 16, 1895, a joint alumni dinner was held at Sherry's, at which all the Schools were largely represented, the number present being something over two hundred. On February 24, 1896, the Council met at the residence of Mr. De Witt. The Standing Committee on Alumni Organization presented a form of circular letter to graduates in other states; a report was presented by the committee having charge of the joint alumni dinner held December 16, 1895; a resolution was adopted recommending a change of the name of the Council to conform to the action of the Trustees in adopting the title of University, and resolutions were adopted accepting the invitation of the Committee on Buildings and Grounds to the members of the Council to act as Marshals upon the dedication of the new site, and undertaking to arrange for a luncheon on Dedication Day. Subsequently about six thousand copies of a circular letter of notice of the dedication were issued, in the name of the Alumni Council of Columbia University, to the Alumni of Columbia College, of the College of Physicians and Surgeons, and of the Schools of Law and Mines, resident in New York and within about thirty miles of New York. On May 2d the members of the Council acted as Marshals, one of the members as Grand Marshal at the dedication of the new site of the University, and a committee of the Council took charge of the luncheon.

The report concludes: "From the foregoing it will appear that the Council has already established itself as a prominent and influential factor in the life of the University, and gives promise of wider usefulness in

the future. What has been done is perhaps only a suggestion of what may be done in carrying out the objects for which the Council was established: to extend the knowledge of the University and its work; to establish closer relations between the Alumni and the University, and to further such measures as, in its judgment, will tend to promote the interests of the University and its several parts."

At the same meeting the Sub-Committee on organization reported that it had prepared a circular letter addressed to Alumni generally throughout the country, suggesting the establishment of local associations, and that several hundred copies of the circular, together with personal notes from the members of the Committee, had been mailed. In most cases the circular was accompanied by a copy of the Locality Index. The committee reported that replies looking to the formation of local Alumni Associations had been received from graduates in the States of Connecticut, Colorado, California, Montana, Wisconsin, Minnesota, Michigan, Missouri and Nebraska, and in Western New York; that Associations had been formed in the States of Connecticut and Colorado, and that sufficient interest had been evinced to justify the belief that continued efforts would result in the formation of a number of State Associations. The Committee requests that any Alumnus who may be inclined to assist in promoting the formation of a local Association will communicate with it.

UNIVERSITY BUILDING.

The "University Building" to be erected on the new site of the University at Morningside Heights, is to constitute one of the central and most important features of the group of buildings, and will stand about two hundred feet north of and fronting the Library.

The large portico, which offers the main approach of this building, faces to the south, and is upon the higher level of the site. The grounds are divided by a transverse retaining wall into two levels, the higher level being 150 feet above tide water; and the lower averaging 120 or 125 feet above tide water. The rear, or northerly portion of the building, is to be erected upon the lower level, and has a greater apparent height. In locating the University Building, Schermerhorn Hall and Havemeyer Hall, which will adjoin it on the east and west, facing south, and having the same front line as the University Building, advantage has been taken of the difference in levels to secure the greatest amount of light and of cubic space without producing an effect of exaggerated height. The lower portion of these buildings, visible only on the north, will be constructed of roughly cut New York stone of a dark gray color. Above the basement, the University Building will be constructed of materials similar to those used in Schermerhorn Hall and the other buildings designed for educational purposes, viz: Harvard brick of a dull red color, and buff Indiana limestone, the latter being used for the portico, and for all decorative features.

The University Building has a frontage of 176 feet and a length of 260 feet. It is planned to serve four distinct purposes, viz: those of a University Theatre; of a Gymnasium; of a "Commons" or Dining Hall, and University Offices; and of a Power House. The power plant will occupy the basement between the retaining wall and the driveway

which intersects the building, where it will be almost completely concealed from sight. The remaining portion of the basement, comprising the great apsidal space at the northern end of the building, is to be devoted to the gymnasium, which will be 170 feet by 130 feet, the ceiling being thirty-five feet in height. A running track twelve feet broad, with nine laps to the mile, will be suspended above the exercise floor. The floor of the gymnasium will be about on a level with the surrounding land, and large and numerous windows will afford ample light and ventilation. Beneath the gymnasium it is planned to construct a swimming pool, semi-circular in shape, 100 feet by 50 feet, with a depth of ten feet, which will also serve as a rowing tank. Immediately above the gymnasium is to be the University Theatre, which will have a seating capacity of 2,500. The theatre will be accessible either through the corridors leading from the portico on the south front of the building, or it can be reached by means of the transverse driveway which crosses the grounds near 119th street and has entrances on both avenues. At the side of this driveway and underneath the building will be a spacious vestibule, from which two broad stairways will lead up to the theatre. The portion of the building which fronts immediately upon the library, will be occupied principally by the "commons," or dining hall, 118 feet in length by sixty-four feet in width and seventy-six feet in height, having a seating capacity of about 600. The remainder of this part of the building will be devoted to private dining rooms and kitchens, and to rooms to be used as places of meeting for the members of the various faculties and for the students. It is intended to make this building the centre of the social life of the University. For commencements and other public occasions the theatre, the hall and other connecting rooms in the southerly portion of the building may be used together, and will provide ample and beautiful accommodations. It is proposed that the interior of the "commons" shall be finished somewhat in the manner of the large halls in the English Universities. The size and proportions of the hall will render it a dignified and prominent feature of the University, and the Alumni propose to give it an historic and personal interest by making it an Alumni Memorial Hall in which shall be preserved the portraits, busts and other memorials of distinguished graduates.

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VOL. XVIII. No. 2. JANUARY, 1897.

THE SCHOOL OF MINES QUARTERLY.

A

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CONTENTS:

Preliminary Hoisting Plant for Mines. By Robert Peele..... 85
Principles of Electrical Distribution.—I. By Francis B. Crocker 93
The Modern Dome. By A. D. F. Hamlin..... 109
Undulations in Railway Tracks. By. P. H. Dudley 119
The Oil Machine. By George Richmond 135
Subterranean Temperatures at Wheeling, W. Va. and Pittsburg, Pa. By W. Hallock 148
Details of Modern Water Works Construction. By Wolcott C. Foster 154
A Few Hints to Students of Irrigation Engineering. By A. M. Ryon, E.M. 161
Correction in Article on The Calculation of Copper Matte Blast Furnace Charges. By H. Van F. Furman 167
Abstracts in Analytical Chemistry. By Elwyn Waller, Ph. D. 169
Book Reviews 176
Alumni and University News..... 185

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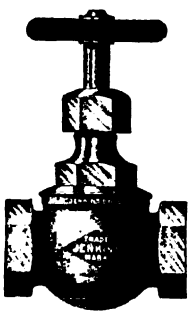

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THE

SCHOOL OF MINES QUARTERLY.

VOL. XVIII. JANUARY, 1897. No. 2.

PRELIMINARY HOISTING PLANT FOR MINES.

BY ROBERT PEELE.

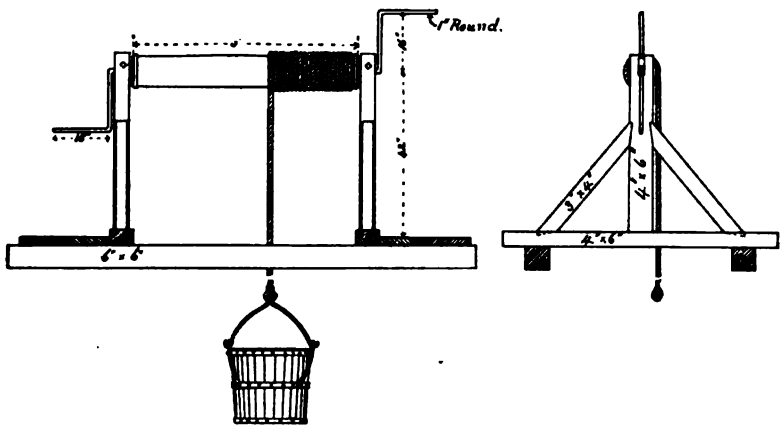
It is intended here to give some account of the hoisting appliances appropriate to the temporary work generally preceding serious mining operations, and which are employed sometimes also in connection with the development of established mines.

The sinking of a prospecting shaft may be followed by actual exploitation on a small scale, and it may be necessary to sink several hundred feet without the use of a steam-power hoist. No sharp line can be drawn between the work of the prospector and the beginning of the development of the mine which results from his discoveries. In every new camp mining may be seen in all of its stages; the use of the hand windlass for beginning a shaft; then, as greater depth is reached, perhaps the introduction of a horse whim, or a light, portable engine and boiler, and, finally, the erection of the permanent hoisting plant.

THE HAND WINDLASS.

The simplest apparatus for hoisting, and in its first cost the cheapest, is the ordinary wooden windlass and bucket. It is used not only for prospecting shafts, but often even in large mines for sinking winzes from one level to another, in places where power hoists cannot be introduced. The winding drum, or barrel, gen-

erally from 6 to 10 inches diameter, is supported by a framework and platform set over the mouth of the shaft or winze (Figs. 1 and 2).



FIGS. 1 AND 2.

Two uprights, say 4 inches by 6 inches in section, are mortised into sills running across the mouth of the shaft, braced as shown on the sketch, and notched at the top to receive the axle of the barrel. Occasionally the uprights are made merely of two pieces of 2-inch plank, spiked to the sills. For the passage of the bucket there is a rectangular opening in the platform, which may or may not be closed by a door when the bucket is being dumped. It is always advisable to cover the mouth of the shaft by a platform, because the edges of the opening are likely to be loose or fissured, so that pieces of rock might be broken away and injure the men below, or in dumping the bucket some of the material might fall back into the shaft.

When the barrel is of small diameter it is hewed or turned out of a solid stick of timber, well smoothed to prevent undue wear upon the rope; or it may be made of a straight section of tree trunk, with the bark removed. For a solid barrel the axle is usually formed by boring a hole in the center of each end, 8 inches to 12 inches deep, and driving in a steel pin, ¾ inch to 1 inch in diameter. The pins are slightly larger than the hole, and the part entering the wood is of square section, or provided with "feathers," to prevent them from turning loose and working out. An iron collar should be shrunk

or driven upon each end of the barrel to avoid splitting. The handles, or cranks, of which there are usually two, are continuations of the axle pins, and are set at 180° from each other. They are operated by from 1 to 4 men, according to the depth of shaft and weight of load. The crank radius is usually 16 inches; length of handle, 15 inches to 20 inches; height of center of barrel above the platform, 42 inches.

Sometimes the barrel is made of larger diameter, up to 16 or 18 inches, and for convenience and lightness is then generally built up like a hollow drum. Two or three thick wooden discs, forming centers, are mounted upon a 4 or 6 inch square wooden axle, which is turned down at the ends to form bearings, or provided with pins, as described above, which pass through iron plates screwed to the ends of the axle. The surface of the barrel in this case is of longitudinal lagging strips, of say 2 by 3 inch stuff. Occasionally windlasses are provided with gearing. In such case ordinary bearings are required for the barrel and separate crank shaft. These ready-made patterns are furnished by several of the mining machinery builders.

The rope is put on the windlass by giving it several turns around the barrel to furnish the necessary grip, and fastening the loose end by a staple. Hemp rope 1 to 1¼ inches diameter is used; sometimes a ⅜ inch soft wire rope. The buckets are generally of wood, bound with iron, though light iron buckets are occasionally employed. They hold, say, from 250 to 400 lbs. There may be one or two buckets. With two a greater net load can be hoisted, because the weight of the bucket is eliminated, as well as that of part of the rope, when the empty bucket is descending. The length of rope required for two buckets is manifestly but a few feet more than for one. Generally speaking, a windlass should be manned by two men. Under no circumstances should a single man be allowed to raise or lower another man.

In point of efficiency and economy nothing can be urged in favor of hoisting by manual labor, except its expediency under temporary conditions and the cheapness and facility with which it may be applied. Much work is done in a small way in every mining district by men whose capital is their muscle and ingenuity, and who are able to "knock together" a windlass and make wages. Prospectors, also, must resort to the windlass if their investigations are to extend more than a few feet below the surface.

An average man will do 2,200 foot pounds of work per minute, and in turning a windlass crank the effort exerted by his arms should not average more than, say, 15 pounds. This gives a proper velocity for the crank of $\frac{2,200}{15} = 147$ feet per minute; or, with a 16 inch crank radius, the speed would be about 17½ revolutions per minute. With a single unbalanced bucket the useful work of a man is reduced to about 1,400 foot pounds per minute.*

The limit of depth to which hand power may be reasonably employed is from 70 to 100 feet, depending largely upon the quantity of water which must be raised in addition to the excavated material. The weight of the rope also enters into the calculation. By using the above data it is found that, in a shift of 8 hours, with a single unbalanced bucket, two men cannot raise more than 6 tons from a depth of 100 feet, and in regular work a duty of not more than 4 to 5 tons should be expected. With balanced buckets, on the other hand, and by employing 4 men, the amount hoisted is much greater: 2,200 ft. lbs. $\times 4 \times 8 \times 60 = 4,224,000$ ft. lbs.

$$\frac{4,224,000}{100 \times 2,240 \text{ lbs.}} = 18.85 \text{ long tons, maximum duty.}$$

The Horse Whim.

When a shaft has become too deep for a windlass a horse whim may be substituted. This useful machine is very extensively em-

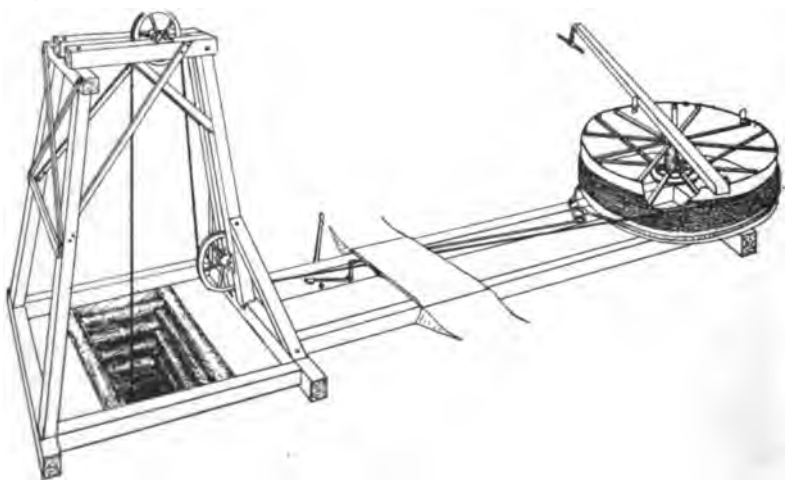


Fig. 3.

* These data are from actual work. See Colliery Engineer, June, 1895, p. 257.

ployed in the mining regions of the United States for depths not greater than, say, 250 to 350 feet. In Mexico and South America, however, it is often used for shafts of much greater depth. The whim is light, inexpensive and is easily and quickly erected. Several types of the apparatus are shown by Figs. 3, 4 and 5.

In one of the simplest forms (Fig. 3) the drum is set upon a vertical shaft, and has a long arm, or "sweep," to which the horse

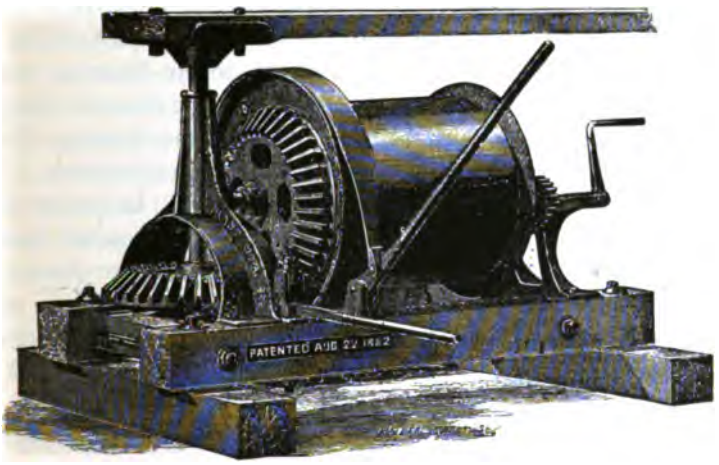


FIG. 4.

is attached. More power is gained by introducing gearing (Fig. 4), and this is often done, though the weight of the machine and its cost are correspondingly increased. Fig. 5 shows a serviceable form of mining whim frequently employed in the West. It

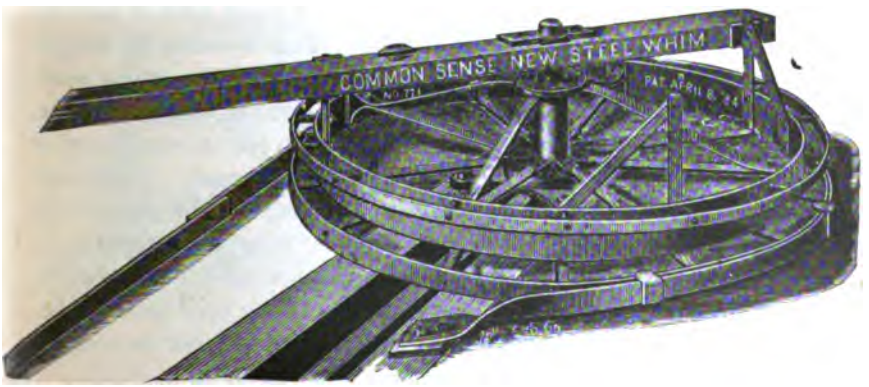


FIG. 5.

is set upon a light timber foundation, the frame and drum being of iron.

The drum should be placed far enough from the shaft to allow ample room for handling hoisted material, etc., between the circular path traversed by the horse and the shaft mouth. With a vertical drum the rope must be led off horizontally, the horse stepping over it at each turn. At a little greater cost the drum can be set lower, so that the rope runs in a shallow, covered trench, thus leaving the surface unobstructed. Close to the shaft collar is a small sheave, under which the rope passes to the hoisting sheave, mounted on the frame over the shaft. When the drum is mounted horizontally the rope may be led directly to the hoisting sheave with sufficient head room for the horse to pass underneath. This plan requires a stronger frame ("gallows-frame") braced to withstand the diagonal pull of the rope. It is found in practice that the minimum diameter of the circle traversed by the horse should not be less that 20 feet; better 25 feet, or more. If it be too small the animal is worried by the work, and is apt to injure his legs by interfering. It is well to make the whim sweep from 12 to 16 feet long.

The work done by an average horse per minute is taken as 19,600 foot lbs.; speed of travel while hoisting, 3½ to 4 miles per hour, and the average tractive force about 55 lbs. The power developed and the hoisting speed will then depend upon the relative diameters of drum and the circular path traversed by the horse.

Duty of One-Horse Whim. With a well constructed whim the duty of a single horse may be taken as a gross load of 600 lbs. raised at a speed of 35 feet per minute. This includes the weight of bucket and rope. With an unbalanced bucket the *useful* work of a horse is reduced from 19,600 to say 14,000 ft. lbs. per minute. Under these circumstances, at a depth of 250 feet, a maximum of 15 tons can be hoisted by one horse in 10 hours. Light steel buckets for whim work weigh 200 to 300 lbs., and the rope would generally be of steel, ½ or ⅝ diameter, weighing respectively 0.35 and 0.60 lb. per foot. One-horse whims have been used to as great a depth as 450 ft., but such practice is very unusual, because the speed must be slow and the net load reduced on account of the weight of the rope.

Two-horse Whim. With two horses a gross load of 800 lbs. can

be raised 50 feet per minute in regular work. It is generally better to increase the speed than the load, by using a larger drum, because small buckets can be more conveniently handled at the surface. The horses are usually kept at a walk. With gearing the angular velocity of the drum is about one-third that of the sweep, that is, if the bevelled pinion on the vertical shaft have 20 teeth the spur wheel on the drum shaft would have 60 teeth.

For one- and two-horse whims only one man is actually required at the surface; for larger machines two men are employed, one as driver, the other to handle the bucket and brake. Whim horses may be controlled by the voice, being taught to start and stop without a driver. In the United States whims are commonly provided with strap brakes, so that the empty bucket may be lowered while the horse is standing at rest. They are made generally for a single bucket, as a pair of buckets are liable to strike each other in passing in the shaft, but, of course, there are the same advantages in using balanced buckets as obtain with the windlass.

*The Malacate.** What has been said thus far regarding whims applies particularly to practice in the United States, or any district moderately easy of access. In some of the Mexican and South American mining regions, however, distant from the coast and from railroads, and where the introduction of steam power would be difficult, whims of very large size are used, capable of hoisting from great depths, and employed in the regular exploitation of mines. In these countries the machine is known as the malacate. This form of whim has been used to some extent also in the western and southwestern parts of the United States. As shown

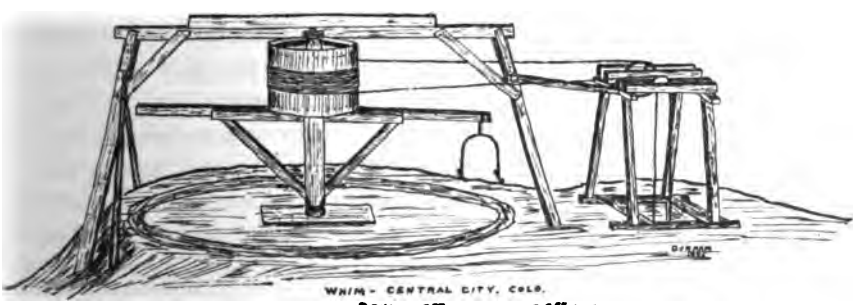


FIG. 6.

*Spanish. Pronounced mah-lah-cah'-tay.

by Fig. 6 it consists of a large drum mounted 8 or 10 feet above the ground upon a heavy vertical shaft or spindle. To the drum and shaft are attached a pair of sweeps. The drum has a light but strongly braced skeleton frame of steel or wrought iron, though the smaller sizes are often made wholly of wood. A stick of timber, 6 by 6 or 8 by 8 inches, with pins let into each end, forms the drum shaft. The lower bearing is a cast-iron socket (or even a hard stone in which a hole is drilled), while the upper bearing is carried by a framework spanning the circular track. The drum is generally from 8 to 12 feet in diameter, with a face 2½ to 4 feet wide, lagged with strips of wood, or covered with light plate iron. Hanging from the extremities of the sweeps, which are frequently 25 feet long, are vertical yokes for one or two mules.* The animals are trained to keep at a steady trot. They reverse the motion of the drum by turning rapidly in their own length—the yokes being swivelled to the sweeps—and trot in the opposite direction. From the drum the rope passes off horizontally to the sheave over the mouth of the shaft. When there are two buckets, as is usually the case, the rope has several turns around the drum to prevent slipping. Brakes are rarely used.

Malacates are frequently erected underground. A tunnel is driven to the vein and the ore lying above having been worked out, the malacate is used for sinking below the tunnel level. To accommodate it a large chamber is excavated in the rock, close to the mouth of the shaft or winze. In the high altitudes of the Andes Mountains this work is severe, and the mules do not often work more than six hours per day, generally in shifts of three hours each. An example may be mentioned of a malacate in a Bolivian mine (the Amigos, at Colquechaca), situated at an altitude of 15,000 feet, which was used to a depth of 750 feet, the shaft being sunk at the end of a tunnel nearly 1,600 feet long. Two malacates were in operation, each with four mules at a time, and millions of dollars' worth of silver were taken out in this primitive way. In Mexico malacates of great size have been employed, operated by from eight to twelve mules. In remote districts both ore and water are sometimes hoisted by raw-hide sacks instead of buckets. They hold from 800 to 1,000 lbs., and are made by trimming a hide to an approximately circular shape; around the

*In Spanish American countries mules are almost invariably used instead of horses, as they stand the work better, especially in high altitudes.

edge holes are cut at intervals, through which a rope or strip of raw-hide is threaded so as to gather up the skin in sack form. As the sack (Spanish, capacho) swings loosely in the shaft, frequently striking against the sides, it does not last long, but possesses the advantages of being light, unbreakable and cheap.

The whim, in any of its forms, is a useful appliance for preliminary mining operations. It is durable and portable and, while the ready-made patterns are commonly used in this country, but little skill is required to extemporize a whim that will serve for sinking to a considerable depth.

PRINCIPLES OF ELECTRICAL DISTRIBUTION.—I.

By FRANCIS B. CROCKER.

The distribution of electrical energy from the generating plant to lamps, motors or other devices involves problems of great scientific and technical interest. It is also a fact that in almost every electrical installation the cost of the distributing conductors is a larger item than that of the generating machinery. This is always true of long-distance transmission, and even in an isolated electric lighting plant the wiring is usually more expensive than the engines and dynamos combined.

Substantially the same principles apply to all branches of electrical transmission and distribution, including electric lighting and power, telegraphy, telephony, etc. But the subject has been developed more thoroughly in the case of electric lighting, which requires a more nearly perfect regulation of pressure and current than the other applications; hence it will be studied chiefly from that point of view in the present case.

Measuring Electrical Conductors. Either the metric system or the ordinary English system of units can be employed to measure the length and size of wires or conductors. The former system, in spite of its many advantages, is rarely used for this purpose in America or in England, and tables or rules employing it would be practically worthless, since they must ultimately be used by common workmen. It should be made compulsory before it can be adopted generally. In English measure we can select either the

mile, yard or foot as the unit of length. The first is too large, as it necessitates inconvenient decimal fractions; the yard is often employed in England to measure electrical conductors, but it is rarely used for that purpose in America, the foot being almost universally adopted as the unit. The size of a wire may be either stated in terms of the numbers of an arbitrary gauge, or the actual diameter in fractions of an inch may be given. Unfortunately the practice of using wire gauges has existed from time immemorial, and results in much confusion because of the great number of different gauges.* This has been overcome to a certain extent in this country by the general adoption of the Browne & Sharp, or American wire-gauge, but this is quite different from the new Standard British wire-gauge, which is used in England. The American wire-gauge will be employed in the present instance, since in this country wires are made and referred to by that gauge very generally, but in many cases it is much better to specify the actual diameter of the wire. For this purpose the word *mil* has been introduced, being a short name for one thousandth of an inch. That is to say, a wire 100 mils in diameter is one hundred one thousandths or one tenth of an inch in diameter. The cross-section of a wire one mil in diameter is called one *circular mil*, being the area of a circle one thousandth of an inch in diameter. Since the cross-section of any other round wire will be proportional to the square of its diameter, it follows that the cross-section in circular mils can be found by multiplying the diameter in mils by itself. We thus avoid the difficulty of converting the cross-section into square measure, which requires the square of the diameter to be multiplied by π and divided by four. This is an awkward and unnecessary calculation in the case of round wires, it being much simpler and equally definite to measure them in terms of a circular unit. The cross-section of the rectangular conductors is defined simply in terms of their breadth and thickness in inches or mils.

For measuring wires or conductors, a wire gauge or a micrometer may be employed. The former consists of a plate having slots in its edge corresponding in size to the gauge numbers. The latter is usually a screw-micrometer which measures the diameter or thickness in mils, that is, thousandths of an inch.

Materials for Electrical Conductors. Copper is the material employed almost universally for electrical conductors, on account of

*Wheeler's Chart of Wire Gauges, the W. J. Johnston Co., N. Y.

its high conductivity. The slight superiority of silver in this respect is more than offset by its higher density.

There are, however, several metals which are lighter than copper for the same resistance. For example, aluminum has a conductivity of 0.542 if copper is taken as unity, and its density is 2.7. Hence, an aluminum wire weighs only $\frac{2.7}{8.89} \times \frac{1.000}{0.60} = 0.506$, or about one half as much as a copper wire having the same length and resistance.*

Although there are several metals that could be used as electrical conductors which are considerably lighter than copper, it is doubtful if it would be desirable to use them, except in special cases where minimum weight is of particular importance, because their bulk would be so much greater. For example, an aluminum wire must have about twice the cross-section of an equivalent copper wire and would, therefore, require much more insulating material to cover it and would be more clumsy, for overhead or underground conductors or interior wiring.

In addition to metals such as aluminum, which may be employed for electrical conductors in place of copper, because they are lighter, other metals and alloys are used on account of cheapness or greater strength. The most prominent of these is iron or steel, which until a few years ago was adopted almost universally for telegraph and telephone lines. But the most recent practice is to employ copper even for these purposes, it being found that the lower resistance, inductance and capacity (because smaller wires are used) more than makes up for increased first cost. Iron has rarely been used as a conductor in electric light, power or other circuits that carry large currents, because of its much lower conductivity, being about one-seventh that of copper. An iron wire must therefore have seven times the cross-section and $\frac{7 \times 7.8}{8.89} = 6.14$ times the weight of an equivalent copper wire, and would cost about as much.

Nearly all alloys also have a considerable lower conductivity than pure copper, so that they are not very generally used even for overhead conductors. In the latter case, hard-drawn wire is employed, having a conductivity about 2 to 3 per cent. less than that of annealed copper.

* The conductivity of aluminum varies somewhat depending upon its purity.

Electrical Resistance. In electrical distribution the most important factor is resistance, from the scientific as well as from the commercial points of view. It entirely determines the flow of a direct current, and largely affects alternating current circuits also, necessitating the use of large quantities of copper for conductors, the cost of which constitutes the chief item of expense in almost all electrical plants or systems, as already stated.

Resistance appears as a serious difficulty in electrical distribution, producing three objectionable effects. First, it causes a *drop* in voltage, so that the various lamps are not supplied with sufficient pressure or with the same pressure; second, it involves a *loss of energy* and efficiency, and third, it produces *heating* of the conductors, which may destroy the insulation or give rise to danger of fire. Each of these effects will be considered separately later.

The determination of electrical resistance can easily be made either by calculation or by actual measurement. It is not necessary here to explain the many well-known ways of measuring resistance, such as the Wheatstone bridge and the fall of potential methods. These may be found in almost any electrical work. Furthermore, it is the usual practice to determine the electrical resistance of conductors in electric light and power distribution by calculation based upon certain recognized standards. This may be verified by tests of samples of the wire or by measurements made after the conductors are laid.

The Standard Conductivity of Copper. It is almost universally customary to express the comparative conductivity of samples of copper in terms of Matthiessen's standard. Unfortunately, Matthiessen gave, at different times, several values which do not agree exactly. To overcome this difficulty, a committee of the American Institute of Electrical Engineers carefully investigated this question and recommended a general acceptance of a definite value for Matthiessen's standard. It is possible to obtain copper of greater purity and higher density than that used by Matthiessen, so that a somewhat better conductivity of 102, or even 105 per cent. of the standard may be reached. But practically all commercial copper is below Matthiessen's standard.

A complete table was prepared by the committee of the American Institute of Electrical Engineers,* giving the resistance, weight,

* Transactions, Vol. X., 1893.

etc., of the various sizes of wire, in both the American and English systems. The resistance of any copper wire at 20 degrees C. or 68 degrees Fahr., according to Matthiessen's standard, may be calculated by the following simple formula: $R = \frac{10.35l}{d^2}$, R being the resistance in international ohms, l the length of the wire in feet, and d its diameter in mils. The latter is easily determined with accuracy by means of the ordinary screw micrometer. A very simple and convenient rule to remember is the fact that 1,000 feet of No. 10 A. W. G. wire, which is practically one-tenth of an inch in diameter (.1019), has 1 ohm resistance at 20 degrees C. (68 degrees Fahr.), and weighs 31.4 pounds. A wire three sizes larger, that is, No. 7, has twice the cross-section and weight per thousand feet, and one-half the resistance. A wire three sizes smaller, that is, No. 13, has one-half the cross-section and weight and twice the resistance per thousand feet. Another, three sizes smaller, that is, No. 16, has one-fourth the cross-section and weight and four times the resistance of No. 10, and similarly a No. 4 wire has four times the cross-section and weight and one-fourth the resistance of No. 10. This may be carried to the extreme limits of the gauge in either direction, the cross-section doubling with each three numbers. Intermediate sizes may be approximated by interpolation; for example, No. 8 wire is about two-thirds larger than No. 10.

Temperature Coefficient of Copper. The effect of variations in temperature upon the conductivity of copper was given by Matthiessen,* his results being usually put in the following form:

$$R_t = R_0(1 + 0.00387t + 0.00000597t^2).$$

in which R_t is the resistance of a pure copper conductor at any temperature t in centigrade degrees, R_0 being its resistance at 0°C.

It is doubtful, however, if this complicated formula is any more correct than the very simple expression:†

$$R_t = R_0(1 + 0.004t).$$

Matthiessen found nearly all pure metals to have substantially the same temperature coefficient as copper, the only important exception being iron and liquid mercury. The values given for these

**Philosophical Transactions*, 1862.*

†*The Electrical World*, Feb. 16, 1896.

metals are somewhat variable, but are about 0.0045 for iron and about 0.0009 for liquid mercury.

The resistance in ohms of a copper conductor at a given temperature is calculated, according to Matthiessen's results, by the formula:

$$R_t = \frac{9.587(1 + 0.00387t + 0.00000597t^2)l}{d^2},$$

which gives the same figures as those of the table of the American Institute of Electrical Engineers, already cited. But if the simpler temperature coefficient is adopted, approximately correct values are obtained from the following expression:

$$R_t = \frac{9.6(1 + 0.004t)l}{d^2}.$$

In fact, the variation in resistance of copper is so great with ordinary changes in temperature that it is rarely possible to predetermine it with great accuracy. The temperature of an overhead line may vary from natural causes enough to alter the resistance about 25 per cent. A further increase due to the heating effect of the current would make a total change of about 40 per cent. in resistance. Underground and interior conductors are not subject to such extreme variations in the temperature of their environment, but it often amounts to many degrees, particularly for the latter, and the heating effect of the current may be equally great. Fortunately, however, in electrical transmission or distribution the current does not ordinarily heat wires more than 5 or 10 degrees, the loss of voltage being usually the controlling factor. Under the head of current capacity the rise in temperature of the various kinds of conductors will be discussed later.

In any given case the probable temperature around a conductor and the rise due to the current can be at least approximately determined, so that resistance calculations can be made accordingly.

It is customary to specify in plans and contracts that copper for electrical purposes shall have a conductivity not less than 98 per cent. of Matthiessen's standard. In some cases only 96 per cent. is required, but it should not be allowed to fall below this limit, as it is perfectly practicable to obtain copper of such quality, and inferior grades would not be enough cheaper to make up for their lower conductivity. Allowance should be made for this fact in calculating the resistance of conductors.

The drop, or lost pressure in volts, is very easily and definitely determined from Ohm's law, by changing its ordinary form $I = \frac{E}{R}$ into $E = I R$. This is not only true of the whole circuit, but also applies to any portion or branch of the circuit, and ordinarily it is far simpler and more likely to avoid errors if each part of the circuit is considered separately. In the case of a very complicated electrical system, it would be practically out of the question to treat the circuit as a whole, but it is always possible to divide the system of conductors into separate lengths, in each of which we can determine the current, the resistance, and therefore the fall of potential which takes place. In most practical work the current is given, since it is usually known how many lamps or how much power is to be supplied. It then becomes necessary to calculate the value of the resistance in order to have the proper value for the drop, the latter being assumed or fixed by the conditions in each case. The common idea that a short conductor of very large diameter has no appreciable resistance is quite fallacious. For example, a bar of copper one foot long and one inch in diameter has about one hundred-thousandth part of an ohm resistance. While this may be a negligible amount in most cases, it is always perfectly definite, and is often quite appreciable. Such a rod would carry one thousand amperes with a drop of one hundredth of a volt between its ends, or ten volts per thousand feet, which is by no means insignificant. Bars of this size or larger are often used in practice carrying correspondingly large currents, hence it is not safe to ignore resistance, even in the case of very large conductors.

Loss of Energy. The second objectionable effect which resistance produces in electrical distribution is the loss of energy which it occasions. This loss is absolute, and must always occur whenever a current flows though a resistance. The exact value of this loss is given by the expressions:

$$\text{Watts lost} = I^2 R = E I = \frac{E^2}{R}$$

in which I is the current in amperes, R is the resistance in ohms, and E is the drop or lost pressure in volts, being applicable either to the whole circuit or to any part of it. From one of these expressions the loss of energy can always be ascertained, provided

any two of the three quantities are known. These expressions give the loss which occurs continuously so long as the current flows; that is, it is the rate of dissipation or energy or the power wasted. For a given time t in seconds—

$$\text{Loss of energy} = I^2 Rt = E Ir = \frac{E^2 t}{R}$$

If it is desired to convert the loss of energy into heat units, any of the above values may be multiplied by 0.24, since one watt-second is equal to 0.24 of a gram-degree.

This loss of energy, while quite considerable in almost every electrical system, usually amounting to from 5 to 25 per cent., is rarely the controlling consideration in electric lighting. The *drop*, which has already been considered, and the *heating limit*, which will be considered later, are usually of more consequence than the mere waste of a small fraction of the total energy, the success or failure of an electric lighting plant being dependent upon keeping them within certain limits.

Economy in Design of Conductors. In many cases, particularly for long-distance transmission in contradistinction to local distribution, the relation between the first cost of the conductors and the energy lost in them may be a matter of prime importance. This subject was first attacked in 1881 by Lord Kelvin, who read before the British Association a paper on "The Economy of Metal Conductors of Electricity," in which he attempted to give a general solution of the problem. The conclusion reached by him, and now known as "Kelvin's Law," may be stated in the following language: The most economical area of conductor is that for which the annual interest on capital outlay equals the annual cost of energy wasted. In other words, the total annual expenditure for interest on the investment and energy lost on the line is a minimum when these two items are equal to each other.

The importance of this law has usually been greatly overestimated, but gradually its limitations have been brought out. In 1886 Professors Ayrton and Perry showed, in papers before the Society of Telegraph Engineers and Electricians, that Kelvin's Law applies only in certain cases, and they gave various modifications and extensions of the law. Professor George Forbes has also contributed to this subject in his Cantor Lectures of 1885,* in which

* London *Electrician*, Vols. XV. and XVI.

he showed that the portion of the investment which is not proportional to the cross-section of the conductor should be kept separate so that the amended law becomes: The most economical area of conductor is that for which the annual cost of energy wasted is equal to the annual interest on that portion of the capital outlay which is proportional to the area or weight of metal used. Professor William A. Anthony, in an article on "Economy in Conductors, and the Limitations in the Applicability of Kelvin's Law,"* demonstrates that in some cases Kelvin's Law gives absurd results, and may, for example, require that *all of the energy should be wasted in order to secure the highest economy.* This is due to the fact that the minimum *expense* of operationis considered, and the energy *delivered* at the end of the line, which is still more important, is entirely ignored. In fact, a great many laws of this kind can be deduced according to what factors are considered. Abbott † and Kilgour ‡ give 15 possible combinations, but state that only 11 of them are likely to be of any practical importance, Kelvin's Law being only one of these cases. But all of these solutions of the problem are of somewhat doubtful practical value, and it is probably true that Kelvin's Law, or any modification or extension of it that has yet been brought out, has done far more harm than good in electrical engineering. It gives a false confidence in the results of calculations which may be totally at variance with real commercial economy. The reason for this difficulty lies chiefly in the fact that the actual costs of some of the items cannot be expressed, even approximately, as mathematical functions. Furthermore, various incidental factors and particular conditions arise, such as the available sizes of machines, which render a general solution of this problem of little practical value.

In this connection it is a common mistake to forget that the interest and depreciation on the investment is a fixed and irretrievable expense, while the energy lost on the conductor depends upon the power transmitted. If the plant is lightly loaded, or is shut down entirely, owing to hard times, strikes, etc., the fixed charge runs on as usual, but the energy loss is greatly reduced, or stopped altogether. Hence it is not wise to lay the full amount of copper corresponding to the maximum or even ordinary demands,

* *Electrical Engineer*, Oct. 31, 1894.

† *Electrical Transmission of Energy*, p. 457.

‡ *Electrical Transmission*, Lond., 1893.

as there is no control over the investment after it is once made, whereas the energy loss adjusts itself to the working conditions.

Probably the safest, as well as the quickest, method to arrive at a correct result would be to obtain a general solution of the problem by means of some form of Kelvin's Law; then this result should be carefully checked by assuming a larger and also a smaller wire, and estimating the economy that would be secured if they were substituted for the size of wire obtained by the calculation. The difficulties of determining the various items of expense are greatly reduced by assuming a certain size of wire, and the various factors, which would be almost impossible to cover by a general formula, immediately become definite. Scientific and rational methods should always be preferred to empirical ones, but every experienced engineer will admit that when complicated questions of cost arise it is unwise to rely entirely upon general formulæ, which are almost necessarily abstract and incomplete. The attempt to force science beyond its legitimate limits has done great injury to many industrial enterprises as well as to science itself.

Current-Carrying Capacity of Conductors. The third objectionable effect of resistance in electrical distribution is the heating which it causes. The production of heat in an electrical conductor has already been stated in terms of the various quantities involved. This heat is an absolutely definite and unavoidable result of the flow of the current. Its effect is to raise the temperature of the conductor, and this rise continues until the heat lost is equal to the heat generated; then the temperature becomes constant. It is obvious, therefore, that any electrical conductor is only capable of carrying a certain current with a given elevation of temperature, and in practical work the allowable temperature is limited by considerations of injury to insulation, danger of fire, etc. No exact general rule for current capacity can be given, as much depends upon the conditions in each case. But, since a wide margin must be allowed between the danger point and the permissible current capacity, it is possible to establish rules which are somewhat arbitrary, but sufficiently safe in almost any case. This is practicably the basis upon which tables are made giving the current that it is allowable for any size of wire to carry. These tables are largely the results of experience, but can be arrived at more or less accurately by calculation.

The following are standard tables of maximum current-carrying capacity of different sizes of wire.

A. W. G.	Table 1.	Table 2.	Table 3.
0000	175	218	312
000	145	181	262
00	120	150	220
0	100	125	185
1	85	105	156
2	70	88	131
3	60	75	110
4	50	63	92
5	45	53	77
6	35	45	65
8	25	33	46
10	20	25	32
12	15	17	23
14	10	12	16
16	5	6	8
18	3	3	5

Table No. 1 is based upon Kennelly's experiments, and is intended to allow a rise in temperature of 75 degrees Fahr. for twice the current specified, thus allowing an ample factor of safety. The normal current would only raise the temperature about 19 degrees Fahr., the heating effect being proportional to the square of the current. The rules of the National Board of Fire Underwriters permit a current density about 25 per cent. greater than the foregoing, the figures being given in Table 2. This would give a temperature elevation of about 30 degrees Fahr., and would still allow a considerable increase (about 60 per cent.) in current above the normal without injurious effects. This table covers "concealed work," and Table 3, which permits a still greater current density, is used for "open work."

Series Systems of Distribution.

The simplest arrangement of lamps or other devices to be supplied with electrical energy is a series system, in which the current from the dynamo *D* passes first through one lamp, *L*, and then through another, and so on, as shown in Fig 1. In such cases the current is usually constant, hence the expression *constant current* is practically synonymous with *series* in electrical distribution. The term *high tension* also applies, since the voltage usually employed is high, being equal to the pressure consumed in each lamp

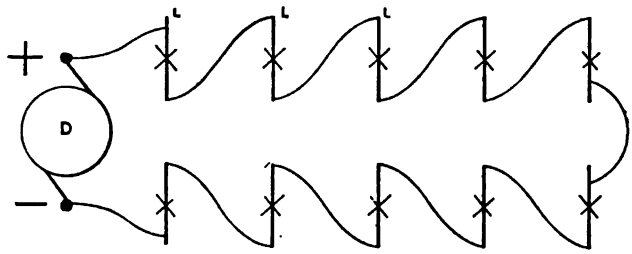


FIG. 1.—SERIES ARC CIRCUIT.

multiplied by the number of lamps. For example, sixty lamps are commonly placed upon a single arc-lighting circuit and, since each lamp requires fifty volts, it follows that the total pressure is 3,000 volts. The problem of designing or studying series circuits is not difficult, the path of the current being usually simple, and the current constant throughout the circuit. This last statement is only true, however, if the leakage of current is insignificant, which is generally the case in electric light and power distribution.

Distribution of Potential on Series Systems. The potential on a series system falls throughout the circuit in direct proportion to the resistance. That is $E=CR$, the difference of potential E in volts between any two points being equal to the product of the current C in amperes and the resistance R in ohms. This simple fact completely covers any possible problem that can arise in connection with a series system, provided a direct current is used, and is easily applied in almost any case. In Fig. 2 an arc-lighting system is represented, D being the dynamo and L, L, L the lamps, connected in series. The total difference of potential generated by the dynamo is 1,000 volts, measured between the two brushes marked + and —. This potential falls as the current traverses the circuit, fifty volts being consumed per lamp. This is made up of forty-five volts actually used in the lamp itself and a drop of five volts on the conductor between two lamps. That is, the drop on the line wire is 10 per cent. of the total E. M. F. The relative potential of the various points on the circuit is easily found. For example, between the + brush and the middle point M of the circuit there is a difference of potential of 500 volts and the same amount between the middle point and the — brush. Similarly any two points on the circuit will have a difference of potential equal to fifty volts multiplied by the number of lamps between them.

Personal Danger from Series Circuits. If a man standing on the ground touches a very highly insulated circuit, only a very slight current will pass through his body, but if the insulation is low or any defect exists at any particular point, then a considerable current may flow through his body. In Fig. 2 the circuit is supposed

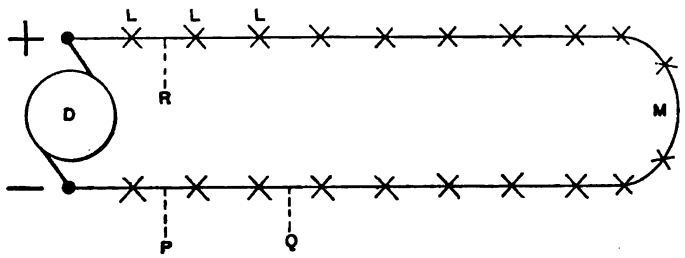


FIG. 2.—DISTRIBUTION OF POTENTIAL ON SERIES SYSTEM.

to have a ground connection at the point *P*. This will cause the potential to be zero at that point; consequently a man may stand on the ground and touch the circuit at that point with perfect impunity. If, however, he touches the wire at the point *Q* he will receive a barely perceptible shock due to 100 volts, since there are two lamps between that point and the ground connection; but if the circuit is touched at that point *R* the difference of potential between it and the ground connection being 900 volts will produce a dangerous or perhaps fatal current. When the defect in the insulation does not amount to what is called "dead ground," but has a resistance, for example, 1,000 ohms, then a man touching the wire at the point *R* will receive a shock due to 900 volts, but the resistance of the ground connection, which is 1,000 ohms, will be in series with his body, and consequently the current will be less, and, assuming the resistance of his body to be 1,000 ohms, the current will be one half as great as in the first case. If the ground connection has a resistance of 8,000 ohms the current through the body would be $\frac{900}{8{,}000+1{,}000}=\frac{1}{10}$ of an ampere, which is not dangerous. We may sum up these various cases as follows:

1. A very highly insulated direct-current electrical circuit may be touched at any one point without danger by a man standing on or in connection with the ground.

2. If a ground connection exists on an electrical circuit the

danger of touching the circuit increases directly with the resistance between the ground connection and the point of contact.

3. The resistance of the ground connection is in series with the body of any one connected with the ground and touching the wire.

4. It is never safe, however, to assume the insulation to be perfect or that a ground connection exists at some particular point, or that it has a high resistance. The circuit should always be treated as if the most dangerous possible conditions existed.

Regulation of Series Systems. The condition required on series circuits is usually the maintenance of a *constant current.* This is accomplished by designing the dynamo so that it will automatically generate a nearly constant current. The various dynamos used in series arc lighting, such as the Brush, Thomson-Houston and Wood machines, are well-known examples of this type of generator. They are provided with regulating devices, which either shift the brushes or vary the strength of the field, or both, in order to keep the current at a constant value. In addition to these special regulators such machines are so designed that they have considerable self-induction, resistance and armature-reaction, all of which tend to prevent the current from rising to a high value, even when the machine is short-circuited.

Series Arc-Lighting System. The general arrangement of the apparatus and circuit is represented in Fig. 1. The dynamo and lamps may be selected from the various well-known and thoroughly successful forms of constant-current arc-lighting apparatus. The determination of the size of wire is not very difficult. General custom and considerations of strength require that no wire smaller than No. 8, A. W. G., should be used. Similarly it would not usually be necessary to employ a conductor larger than No. 4, because the potential being high, and the current small, the loss of energy is not great in a wire of several miles in length. To take a specific case, let us assume a circuit five miles long, supplying 80 arc lamps, the potential being 4,000 volts and the current 10 amperes. If No. 6 wire is used, the resistance would be 2.1 ohms per mile or 10.5 ohms for the whole line. This involves a drop of 105 volts and a loss of energy of 1,050 watts, which is only 2.63 per cent; consequently it is evident that the use of a little larger or a little smaller wire would not seriously affect the economical working of such a line, and the cost of copper is also small. The

substitution of No. 3 for No. 6 wire would save one-half the loss of energy and the cost of the copper would be doubled. The energy saved, 525 watts, would have a certain value per annum, depending upon the cost of coal and other local circumstances. The larger size of conductor would involve a certain additional first cost. In many cases the larger size of wire might secure a saving of energy greater than the charge on the increased investment; but it should be remembered that the cost of laying and repairing the larger wire would be considerably greater, and its unsightliness would be quite a drawback in the case of overhead conductors. It is therefore very doubtful whether it would pay to put up the larger wire simply to save a small amount of energy, only amounting to about 1.31 per cent. of the total power generated.

Series Incandescent Lamps on Arc Circuits. Several forms of incandescent lamps have been designed and manufactured for use on the regular 10-ampere arc circuits. These consist of lamps similar in general principle and construction to those used for constant potential, parallel distribution, but containing a shorter filament of larger cross-section, that is sufficiently heavy to carry the full current of 10 amperes.

The most important consideration is that of maintaining the continuity of the circuit when the filament of any lamp happens to break, which might occur at any time. This may be accomplished by some form of cut-out, which short-circuits the lamp when the filament is broken. One type of this device is called a "film cut-out" and consists of a thin sheet, *F*, of paper or other material interposed between the points *P* and *P* connected to the conductors *A* and *B* which enter and leave the lamp, as represented in Fig. 3. This film obliges the current to pass through the lamp so long as the filament is intact; but when the latter breaks the difference of potential rises from its ordinary value of 10 or 20 volts to the full E. M. F. of the circuit, which is usually several thousand volts. This high pressure is sufficient to puncture the film, allowing the current to pass directly across between the points *P* and *P*, thus short-circuiting the lamp and re-establishing the continuity of the circuit. In some cases a small electro-magnetic switch is employed, which is caused to close and short-circuit the lamp by means of a magnet connected across as a shunt between the leads of the lamp. The coils of this magnet are of high

resistance and carry little current until the filament is broken, when the full current is thrown through them, causing the switch to close.

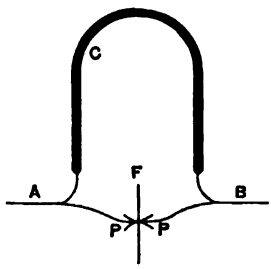


FIG. 3.—FILM CUT-OUT FOR SERIES-INCANDESCENT LAMP.

"Municipal" Series Incandescent Systems. These are similar to the preceding, but, instead of operating with a regular arc-lighting current of 10 amperes, they are usually designed for about 3 or 3.5 amperes. This gives a filament of sufficient length and cross-section to be durable, and yet does not require excessively large leading-in wires. The lamps are made of various sizes, requiring about one volt per candle power. The practice with this system is to feed the circuit with a constant potential, usually 1,000 volts. When the filament of a lamp breaks and it is automatically cut out of the circuit the current increases in strength since the total resistance is reduced, the potential remaining constant. This increase of current is indicated by an ampere meter, or by the brightening of a lamp in the station, and is corrected and brought back to its normal value by switching in an extra lamp at the station. This is usually done by an attendant who is kept on duty to watch the various circuits. The system is rather a crude one, and is rarely used except for street lighting in place of arc lights where the more powerful light of the latter is not required. Several of these circuits may be operated from the same dynamo, all of them being supplied with the same potential. Either the direct or alternating current is applicable to this method of distribution, and both are in actual use. The dynamo is designed to yield a constant potential of a given value, being equal to the sum of the voltages required by the lamps of each circuit. The current capacity of the dynamo must be sufficient to supply the various cir-

cuits in parallel. A shunt or compound wound direct current machine, or a separately excited or composite alternator, would be suitable to the purpose. In the case of the compound or composite machines they should simply give an absolutely constant potential, since the number of lamps, and therefore the drop, on each circuit is constant.

THE MODERN DOME.

By A. D. F. HAMLIN.

As the broad dome of the new library of the University rises daily higher above the surrounding mass, the value and beauty of this feature, both as a part of the structure it crowns and as an element in the landscape, becomes increasingly apparent. A short distance away in one direction the cupola of St. Luke's Hospital challenges attention by the contrast which its more slender and loftier proportions offer to the profile of the library dome; while to the northwest the great conical roof, covering the dome of the Grant mausoleum, furnishes a third variation on the theme of the dome as an external feature. The three together introduce into the landscape silhouette a much-needed element. Hitherto spires, tall office buildings and chimneys have furnished almost the only varieties of upward breaks in the profile of New York, which has been singularly lacking in interesting outlines, especially in the uptown region.

The use of the dome, as a commanding feature of external design, is an essentially modern idea in European and Western architecture. Neither the Romans nor the Byzantine builders, who made of the hemispherical vault one of the most important elements in their architectural design, attempted to give it any importance as an external feature. The dome of the Pantheon at Rome (119 A. D.) is externally almost invisible from the ground, except at a great distance. That of Hagia Sophia at Constantinople, the masterpiece of Byzantine art, dating from 556,* however impressive by its size, has absolutely nothing to suggest that its designers gave any thought to its exterior aspect. The five domes of St. Mark's at

* The original dome, built 532–538 A. D., fell in during an earthquake, and was rebuilt about 556 A. D., with a fuller curve.

Venice required, to please the taste of the fifteenth century and to bring them into some harmony with the splendor of the façade, the addition over them of the present wooden and lead-covered cupolas, which date from the fifteenth century. The exterior treatment of the domes of St. Front at Perigueux (1047) is a modern addition, and all the great domes of Italian churches and baptisteries erected previous to the Renaissance, are either utterly insignificant to external view, or covered by wooden domes or masked by tower-like edifices, wholly unrelated to the form or structure of the vault beneath them. Even the thousand domes of Constantinople, striking and effective in their aggregate effect upon the silhouette of that marvelous city, are individually commonplace and bare externally.

The earliest examples we have of the dome treated as an element in the exterior decorative effect of an architectural design, appear to be those erected by the Arabs in northern Africa, chiefly in Cairo, during the closing years of the Fatimite dynasty, as in the mosque of Barkouk (1149 A. D.); and during the Ayûb dynasty, as in the great Mâristân Kalaoun (1284–1318) and the beautiful tombs of the Karafah. This use of the dome was associated almost exclusively with the idea of sepulture and was a natural consequence of the purpose which dictates the erection of a mausoleum, namely, that of proclaiming to the world, by the external splendor of the monument, the honor of the distinguished dead interred within. These Arabic domes are accordingly given great height in proportion to their diameter; and by the refined and subtle curvature of their profiles, as well as by the extraordinary richness of their surface decoration, they produce a most striking architectural effect, not easily surpassed in its way. All, or nearly all of the domical mosques of Cairo, are tomb-mosques, erected to commemorate deceased Khalifs whose sarcophagi are placed within the mosque enclosure or even under the lofty dome. But these domes, thus designed for external effect, present internally little of the appearance of the dome as used by the Roman and Byzantine builders. Their small diameter and great height suggest rather the effect of "lanterns," such as the Gothic builders of France and England were wont to erect over the crossings of their great churches, as in St. Ouen at Rouen. The simple majesty of the broad hemispherical vault is wholly wanting, and its place is taken by the sumptuousness of complicated and minute decoration by "stalactite" or-

ornament, gilding and color. There was no attempt to combine in one design the conflicting conceptions of the broad, simple hemispherical vault of low curvature for interior effect, and the narrow lofty profile required for external impressiveness.

II.

This conflict between the demands of internal and external effect is the *crux* of dome design. It is this difficult and, at first sight, insoluble, problem which the architects of the Renaissance in Italy undertook to solve. It is the recognition of this problem, and the way in which it was handled, that distinguish Brunelleschi's dome of the Cathedral of Florence (1420–1464) as the initial triumph of the new taste in architecture, quite as much as its marvelous structural design and execution. The mighty octagonal vault, 143 feet in diameter, rises internally to a height of nearly 280 feet, not counting the lantern. It is constructed with an inner and an outer shell, connected by eight major and sixteen minor ribs; the exterior profile being slightly steeper and more acute than the interior. The whole is crowned by a lofty lantern. This last feature is the peculiar glory of the design. The small finials which terminate the Arab domes are an insignificant and trivial capping for the structure beneath. The Italian recognized the necessity of an adequate and richly decorative feature to gather up the lines of the eight angle-ribs of the exterior dome, and to fitly crown its imposing mass. Thenceforward no important dome was erected in Italy, or indeed in Europe, without this feature until within a comparatively recent period.

But the problem of reconciling the conflict between the demands of external and internal effect was not solved. Impressive as the Florentine dome is by its vastness and height internally, the effect it produces is unsatisfactory. It is too high and too dark; it overwhelms and crushes the interior architecture of the nave and chapels below. The low-curved dome of Hagia Sophia, which is but 107 feet in diameter, and only 180 feet high, is far more impressive. Nor is the exterior of Brunelleschi's dome satisfactory. Its bareness, heaviness and size are wholly out of scale with the cathedral to which it was added. But it initiated a series of experiments in dome-building which covered Italy with splendid monuments. The dome became the leading feature of Italian Renaissance church-design, controlling the plan almost as

completely as did the vaulting in the development of Gothic architecture. The only possible principle to be applied to the problem was finally discovered and, during the seventeenth and eighteenth centuries, was universally recognized. It is the domes built on this principle which alone redeem a majority of these late Italian churches from the utter badness of their vulgar details.

This principle was the recognition of the impossibility of meeting both the demands of the problem by one and the same structure. Accordingly there was provided for interior effect a dome of moderate height and low curvature, in scale with the treatment of the nave and choir, and not too lofty to be reached over its whole surface by the direct or diffused light which pervaded the church. Outside and above this rose a drum, decorated with pilasters or engaged columns, and carrying an entirely independent external dome. This was in many cases of wood covered with lead or tile, and bore a graceful lantern, also of wood. Nearly all the Italian churches erected subsequently to the middle of the sixteenth century are adorned with domes on this plan.

It must be evident that once the principle is recognized of the separation of the inner and outer domes it becomes difficult, if not impossible, to set limits to that separation. The two surfaces have become independent structures, whose form and design are controlled by wholly distinct and diverse considerations. The inner dome may be made as low as possible, consistently with good architectural effect. The outer dome may be lifted a hundred or two of feet higher into the air, in order the better to clear the mass of the surrounding structure when seen in perspective from below. The two domes may be, and generally are, of different materials. The lower one may be of masonry—a true hemispherical or domical vault—the upper one of wood or iron, serving as a decorative roof to cover and protect the vault below. The only considerations which control both alike are the fact that, as they are usually carried upon the same substructure of piers and arches, they must be of approximately the same diameter; and that they naturally offer to view the same architectural style and scale of parts. Beyond this there is no closer relation between them than that between the central spire or lantern of a Gothic church and the vaulting beneath it over the crossing of nave and transepts. The one, in each case, is a ceiling, the other a roof. There is no absolute reason, in logic or æsthetics, why both should have similar forms; and

the French Gothic builders, the most severely logical of all artistic builders in the development of their architectural forms, found no contradiction or want of sense whatever in putting a lofty and tapering spire as a decorative roof over the vaulted ceiling of the bell chamber in a church tower, nor in rearing above the intersection of the nave and transepts a lofty square or octagonal lantern, two hundred feet high. The reproach sometimes cast upon the Renaissance architects of the complete separation of the outer from the inner dome in the later examples is therefore a purely abstract and speculative objection, which does not bear the test of careful examination or of practical and artistic considerations. For, since it is in almost all cases—in all cases of long, wide or complex buildings—impossible to make a dome well-designed for interior effect also effective externally, and since the external accentuation of the very important space or rotunda covered by the inner dome is artistically proper and even imperative, the only logical course is to consider the two requirements independently. The use of a domical form for the outer covering is a matter of artistic expediency, not necessity.

This principle seems, indeed, so obvious that one is constrained to wonder at the tardiness of its recognition by the designers of the Renaissance. Michael Angelo, in the middle of the sixteenth century, failed to realize its importance. The dome of St. Peter's as designed by him is far too lofty internally. Externally it is one of the most original, noble and stupendous creations of architectural art in any age. Its vast size—195 feet in diameter over all, through the bases of the engaged columns—its fine profile and well proportioned lantern, and the masterly handling of scale in its various parts, all reveal the work of genius. But the inner and outer shell are too close to each other for the best internal effect.

It was the French architects of the last century who most completely developed the principle outlined above, while, at the same time, they attacked the difficult problem of lighting the internal dome so as to give effect to the paintings which adorned it. This was accomplished by a device of great ingenuity, somewhat theatrical perhaps, but very successful. An intermediate dome was introduced and decorated with a large painting in the upper part. The inner dome was open at the top, the opening so proportioned as to frame the painting above it for the eye of the spectator on the floor far below. The base of the intermediate dome was pierced

with openings, admitting light from the windows in the drum of the exterior or upper dome. This light reflected upward from the convex outer surface of the lower dome sufficed to light up amply the picture above, which, seen from the floor, appeared as if painted on the inner dome, the distance between the surfaces being so foreshortened as to be hardly, if at all, perceptible.

This is the system first devised by Jules Hardouin Mansart in the Dôme des Invalides, Paris (1680), and adopted in modified form by Soufflot in the church of Ste. Genèviève (afterwards called the Pantheon) in 1754. The dome over the Rotunda in the Capitol at Washington is treated in the same way.

The lantern presented another serious difficulty. When the outer dome is of wood it becomes necessary to make the lantern also of wood, unless some means be found of supporting the heavy weight of a stone lantern without loading it upon the inner dome. This latter, owing to its relatively low curvature and the great height and weight of the intermediate tower required to reach the top of the outer dome before the lantern itself appears, is manifestly ill adapted to sustain the lantern. A wooden lantern, even treated with the elegance which characterizes that of the Invalides, is unsatisfactory; it is at best a counterfeit or a travesty of a structure in stone.

The first solution of this problem, by which a stone lantern was made possible without regard to the material of the exterior dome, was that devised by Sir Christopher Wren in St. Paul's Cathedral (1675–1710). Here a cone of brickwork rises from the circle formed by the meeting of the eight pendentives, forms a contracting drum for the inner dome which it supports and envelopes, and rises above it to form the base of a handsome stone lantern. The wooden exterior dome closes around the top of the cone and base of the lantern.

The difficulty in this case, aside from possible objection to the inclined conical-fustum shape of the inner drum, is that the stone lantern looks as if it were carried by the wooden external dome or roof, which is suggestive of an impossibility or at least an absurdity. In the Panthéon at Paris, Soufflot remedied this by making the outer as well as the inner shell of stone, and substituting for Wren's brick cone a structure of parabolic or ovoid section, also of stone, enveloping the inner shell, which was open at the top, and closing over it at a considerable height

with a domical surface on which was the painting, lighted through four great arches cut through this ovoid structure. The height and steep curvature of the latter adapted it for the support of the lantern. The combined weight of the three shells, all of masonry beautifully cut, and made as thin and light as possible, is nevertheless enormous, and the original piers began to yield to the terrible strain, by splintering and cracking. The resulting worry and anxiety probably hastened the death of the architect in 1781. Isabelle strengthed the piers, enlarging their section, and there has been no trouble since.

III.

So far we have briefly considered the dome as a true vault of stone or brick. It was inevitable, however, that the architects of the Italian and later of the French Renaissance, preoccupied as they were with beauty of form rather than with questions of structural logic, should in time enter upon a path leading to developments in which appearances alone would be considered, with all the resulting temptation to sham and meretricious display. It is a principle universally observable in the history of style development, that forms originating in structural design, come in time to be used in a purely decorative way, their original significance being entirely lost. So it came to pass with the dome. Originating as a convenient, economical and effective form of vaulting in masonry, it was treated by the architects of the Renaissance as a decorative ceiling, valuable for the sake of its form and architectural effect, whether built as a vault or not. With the extraordinary development of decoration in stucco and plaster, which marked the sixteenth century, and which in the seventeenth and eighteenth degenerated into a vulgar abuse, the practice crept in of executing panelled ceilings in lath and plaster, and then of imitating vaulted ceilings in the same material on a timber framing. It was the spread of carpentry in architecture that doubtless led to the adoption of exterior domes or shells of wood, and thus made possible the wide separation of the two shells already explained. In the process of time the inner shell, and often the entire "vaulting" (so called) of a church or public building came to be executed, in the majority of cases, in timber and plaster instead of masonry. This cheap and showy style of construction spread through Europe and, though it never quite drove out true vaulting, it prepared the way for the

iron-frame construction of a later day. It was the experience gained in the heavy carpentry of big roofs and of the trusses required for plaster ceilings, vaults or domes of large span that made possible the use of metal trusses when iron became cheap enough and its manipulation sufficiently advanced to permit of such applications. One of the earliest and largest of metal domes was that of the Cathedral of St. Isaac's, at St. Petersburgh (1818–1858), in which the framework is composed of sections of cast iron. But the use of iron for domes has in Europe been mainly confined to museums and exhibition buildings, while those for monumental public buildings of other kinds have, for the most part, continued to be built of masonry.

IV.

The United States inherited the structural and artistic traditions of Great Britain, where lath and plaster were even more abused than on the Continent. The forests of oak and pine of the New World, and the lack of roads and facilities for transporting or handling stone, naturally resulted in carrying to further extremes the substitution of wood for masonry and brick. Until the colonies became independent there was little opportunity for public secular architecture; but the closing decade of the last century witnessed the erection of one monument and the beginning of another, which were destined to exercise a remarkable influence on our public architecture. These were the Massachusetts State House by Bulfinch and the National Capitol, in which Bulfinch had at least a share. In both of these edifices an exterior dome was intended to form the chief crowning feature, and the one in Boston was executed in wood at an early date. It was (and still remains in its original form) a perfectly smooth and somewhat lofty cupola with a lantern, but wholly unrelated to the interior plan of the structure it crowned. That at Washington was perhaps intended to be of stone; it was comparatively low and covered the circular rotunda which has always formed the grand vestibule of the Capitol. With the extension of the Capitol by the north and south wings a more monumental central feature became necessary externally and the present magnificent dome was erected. It is, in spite of its counterfeiting of marble by a sham architecture of cast iron, a very imposing and successful creation, so far as its design and proportions are concerned; but one cannot help regretting

the necessity, whether structural or economic, of so poor a material for the carrying out of so noble a design.

Ever since the inception of these two legislative palaces a dome seems to have been considered an indispensable feature of any and every State House, and city halls and court houses, custom houses and town halls have been erected by the score and hundred, adorned with cupolas and domes of varying degrees of excellence in design. The majority, indeed almost all, have been built of wood or iron. A true masonry dome has apparently been beyond the abilities of our architects or the purses of the cities or States which have employed them, or both. Wood, lath and plaster are perishable, easily become shabby, are subject to decay and in constant danger from fire; but they are cheap and light, and can be built on almost any plan or foundation with the help of posts and trusses. They look for a time as well as stone; the silhouette is just as effective; hence the vast number of these cheap but attractive shams. There are a few exceptions. The domes over the rotundas of the custom houses at New York and Boston are true vaults of granite, designed wholly for interior effect. The great dome of the Low Library is a genuine vault of brick masonry, of the most solid and ingenious construction. The Connecticut Capitol at Hartford has a lofty dome of white marble gilded, as its chief exterior adornment, having no relation whatever to the exigencies of the plan. There are other examples here and there of true masonry domes, but they are few and far between.

Since iron has become so cheap in the United States it has begun to drive out wood in framed structures of any importance. Comparatively few large domes have been erected of late years otherwise than with an iron framework, finished internally with wire lathing and plaster. This is reasonably fireproof and more durable than any wooden construction, but it is at best a counterfeit; and, though such counterfeits always have been and always will be inevitable features of the history of architectural development, one cannot help regretting that they should so frequently take the place of the nobler, if more expensive, masonry. For such lofty and tower-like decorative cupolas as that on St. Luke's Hospital the use of metal is more tolerable. What is really to be hoped for as the next stage of evolution is, however, the development of some combination of metal framework with fillings of

terra-cotta, brick or stone, which shall in its style of design more frankly accord with the character of the materials than any mere imitation of stone. The dome of St. Augustin, Paris, is constructed of such a combination, and is fairly successful. It is precisely the same principle which Mr. Haight adopted with such happy results in the iron and terra-cotta ceiling of the present library of the University. There are great artistic possibilities as yet undeveloped in such a combination.

V.

The great dome of the new library marks another stage and another branch of dome-design, both curious and interesting. From the point of view of construction it reveals a distinct advance in the direction of sound and solid building. As a design it illustrates the rather singular and sudden, and very American, popularity or vogue of the low-crowned dome as an external feature. In a considerable number of recent buildings the effort has been made to secure architectual effectiveness externally with a dome of low curvature fitted to the interior requirements. The beginning of this sudden popularity of an architectual idea which is as yet far from complete or quite satisfactory development can be traced to the Columbian Exposition of 1893. There it appeared in the works of two different architects, in the Art Palace of Mr. Atwood and the Agricultural Hall of McKim, Mead and White, besides a number of minor buildings. Its prototype is evidently the Roman Pantheon, whose vast hemispherical vault appears externally as a low dome rising but slightly above three encircling steps which serve to load the haunches against upward buckling. This dome, however, is almost invisible from the square in front. The modern examples are given a higher curvature and decorated with ribs, decorative scales or tiles, and crowned sometimes with a group of sculpture or a rich finial.

The obvious drawback to this treatment is its ineffectiveness at a near approach and its inapplicability to cruciform or complex buildings, whose projections inevitably hide from view any but a lofty dome, except to a spectator at a great distance. In buildings of moderate lateral extension or of moderate relative height the objection does not hold to the same degree. The new library is so proportioned, and the arms of the cross are so shallow, that the dome will come in view to the spectator at a comparatively

short distance. The building is isolated and crowns a height, so that it is visible for miles around; and these conditions are all favorable to the best effect for a dome of this character. Internally it forms a monumental and imposing ceiling for the very lofty reading room. Its exterior treatment is so simple as to suggest that more thought was given to its effect as a feature in the silhouette of the group of buildings than to its decorative effect at a near view. Externally it dominates and gathers together the masses of the edifice and by its swelling curve compensates for the somewhat severe simplicity of those masses. What it most lacks as a decorative feature—which indeed, as I have just said, it seems hardly to have been intended primarily to be—is the accent and interest of a lantern. But a lantern is a very difficult thing to treat, if not to construct, on so low curved a dome; and the lack, if it be a defect, this dome must share with all others of its class.

UNDULATIONS IN RAILWAY TRACKS.

By P. H. DUDLEY.

As my Track Indicator runs over the road at 20 miles per hour, under the 6,500-lb. wheel loads and for the 11-foot wheel base of the special 6-wheel truck, both rails are made to autographically indicate their own condition as to surface, due to the rails, ties, ballast, road-bed and labor. The car containing the Indicator is 58 feet long and weighs 72,000 pounds.

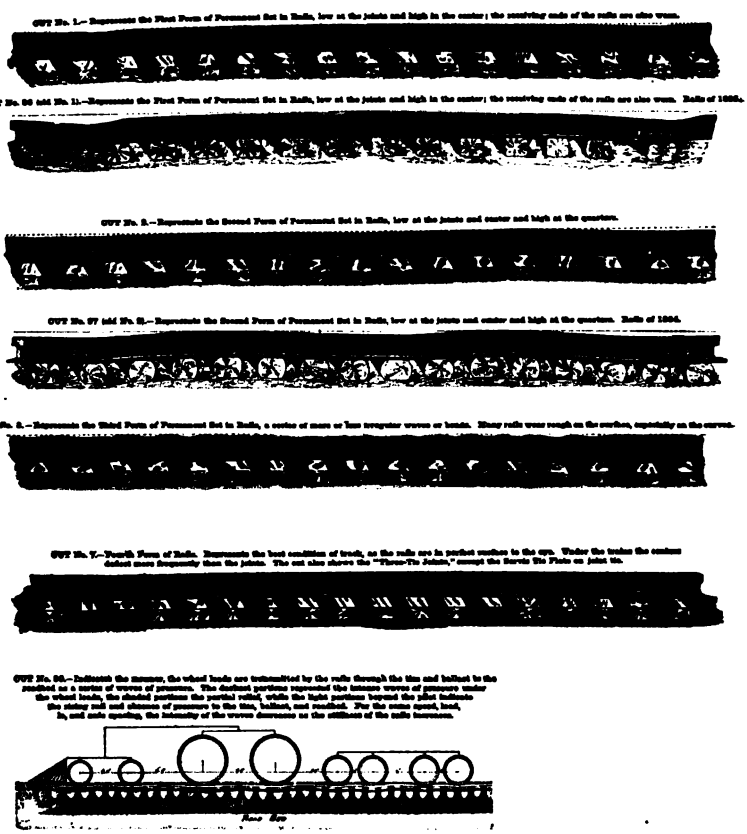
A study of the original diagrams of the track from various roads taken many years ago indicated at once that the undulations in railway tracks under moving trains were of two kinds, viz:

1. Those which were due to the permanent set of the rails.

2. The deflections of the rails and ties and the depressions of the ballast and road-bed until the total resistance equals the load.

The permanent set in the rails was studied and I found they could be classified under three general types which I called forms of permanent set.

The first form embraced all those rails which were low at the joints and high at the center. This type was found upon rails laid with opposite joints. See cuts Nos. 1 and 36.



NOTE.—In the reproduction of Cut No. 7, the center of the rail has raised; it should be a plane surface between joints.

The second form of permanent set embraced all those rails low at the joints and center but high at the quarters. This type was found upon rails laid with alternate joints; if, however, the traffic was heavy, and only a small force employed, the second form would be soon converted into the first. See cuts Nos. 2 and 37.

The third form was due to a series of minute waves in the surface of the rails.

Combinations of the first and third forms, and of the second and third forms were frequent. The first and second forms of set were developed in the track by service, while the third form was due to improper finish at the mills. See cut No. 3.

For the rails to take a set in the track it was very evident that

the fibre stresses in the rails, often exceeded the elastic limits of the steel. This was in 1881, and as a rule the steel rails then in the track were the first used by the roads; and as the normal condition of the former iron rails in the tracks was one in which nearly all of the rails had taken a set, this feature in the steel rails excited very little comment among the trackmen, but among the officials the matter received more serious consideration.

It was evident that the standard of tracks being maintained was too low for the increasing traffic of the roads.

The first remedy proposed by the Railway Companies was to increase the track force and add more ballast to the track.

Short, 4-bolt angle-splice bars were being adopted, replacing the common fish plates. Railway officials had watched their deflections under trial engines at slow speed, and concluded that the joints did not deflect any more than the center of the rails.

No analysis was made of the matter, and the reason for like deflections was not understood. The joint ties had been tamped, while the center of the rail was high and loose and only came down to the ties as the wheels passed over it. The comparative stiffness of the joints with the center of the rails was more apparent than real.

The general length of the rails in the track then was 30 feet, as now, joined and held together by a number of kinds of joint fastenings, though the fish bars and the angle-splice bars were the most common.

Chair joints and bridge joints were also in use. There was not a single form of joint fastening which would hold up the rail ends without constant surfacing and attention. The joints were down, the rails had taken permanent set of the forms already described, while the receiving ends of the rails were cut out in double-track roads. The track and road-bed had not only to carry the wheel loads, but to take up and absorb the dynamic effects, which in many cases were greater than the static wheel loads.

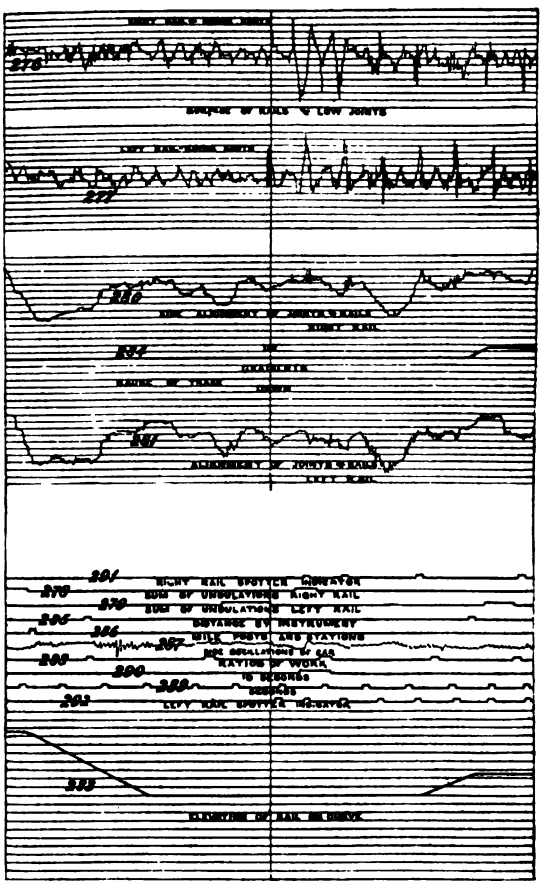
The joints were and are still the weakest points in the track, for no joint fastening has yet been designed, which can transmit the horizontal components of stress from one rail to another in distributing the wheel loads, consequently there is an increased transmission of pressure to the ties and road-bed at the joints from any passing wheel.

In 1881 there were still many of the light steel rails in the track which originally cost 120 to 140 dollars per ton in gold.

In order to save as much as possible in the first cost of the rails per mile, the weights per yard were kept as low as they considered would be safe for the traffic. Sections of 56 pounds to 60 pounds per yard were very common while a 65-pound section was considered a heavy section, 67 pounds being the heaviest in use and that by only one road.

The height of sections ranged from 4 to 4½ inches, so that any form of fish or splice bar would be quite weak, and it is not strange that the trackmen let the joints go down and the rails take a set.

The undulations in the track were very decided, and are well shown by the reduced diagrams shown in cut No. 5, though these



Cut No. 5, showing reductions from diagrams taken in 1882. On the left hand is a representation of best tracks at that date; and on the right, fair track. In either hand the rails were loose; joints low on the right hand. See Cut No. 27 for surface of rails and joints in 1894.

were taken in 1882. It was clearly seen from the diagrams that the undulations of the rails per mile, as well as the smoothness of the surface varied much per mile, and it was desirable to have a closer estimate of the amount of undulations per mile, although these could not be estimated from the diagram except by an amount of labor which soon became impossible to devote to such work.

The summing-up mechanism which I had designed in 1880 was completed for the fall inspection of the tracks in 1881. The number of feet of undulation per mile as summed up by the instruments on the best track of comparatively new rail was about 6 feet per mile, while on the older rails, not in as good condition, the amount would often be 10 to 12 feet per mile.

The general average for a number of roads was about 8 feet per mile. None of the tracks, particularly on the 4-inch rails, had what we would now term a high degree of stability, for they required constant attention to keep them in what was called good condition. The labor on the tracks only made them temporarily but not permanently better.

The number of feet of undulation per mile, as summed up by the instruments for each line of rails, was tabulated, and the mean taken. As had previously been indicated by the diagrams, the variation per mile was very marked. At first the railroads only wished to know the total for the road and the average per mile, so a comparison could be made with the standard of track of other roads.

This was far too general for detailed work, for it was important to know why some miles were better than the average, in order to direct the work so as to raise the general average.

The mass of figures for a road could not be carried well in the mind; so I designed the condensed diagrams which would not only show graphically the general condition of the road at a glance, but the details per mile. See cut No. 38.

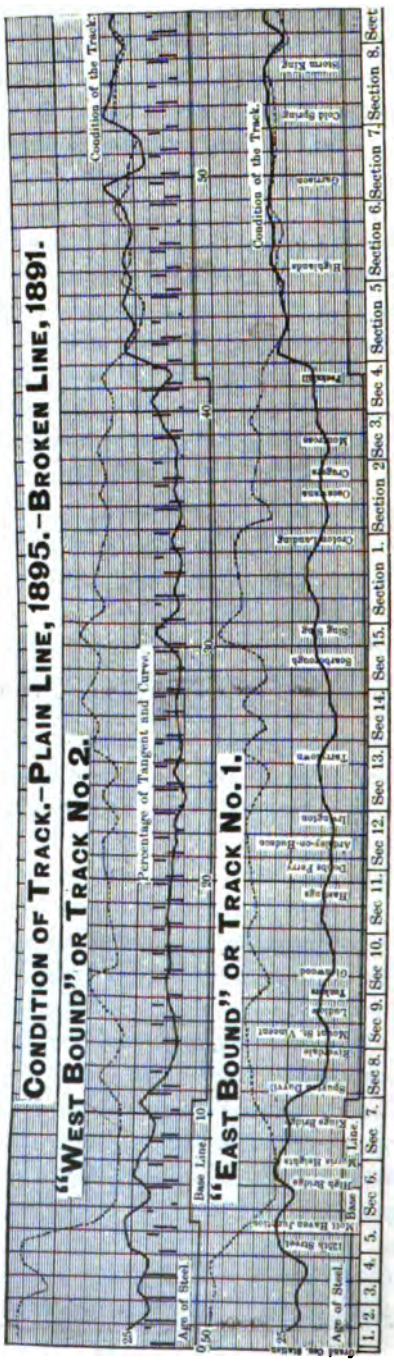
The condensed diagrams for 1881 were very striking, and for those miles on the heavy gradients and others which exhibited the greatest amount of undulations, the Railroad Companies thought by putting more labor on them they might be made equal to the best.

In the meantime, in order to make the work as practicable as possible for the Department of Maintenance of Way, in 1882, the

"Markers" were added for ejecting paint on the rails when the deflections exceeded $\frac{5}{16}$ of an inch. This was very convincing, and left little doubt in the minds of many officials that the deflections of the rails in the track were greater than they had anticipated.

The rails were marked so that the officials and trackmen could see where the deflections occurred under trains, which was not only a great educator to them, but directed the work to the places needing most attention. The diagrams for 1882 repeated all the striking characteristics of those for 1881; not an important curve per mile on the condensed diagrams had been reversed unless new rails had been laid. The rails which were rough on the surface had not and could not improve after another years' service; joints which were down the year before were still down, and little, if any, permanent improvement had been made.

The dynamic effects of the wheel loads of the increasing traffic were too great for the track to improve, and some railway officials accepted the fact



Cut No. 38, P. H. Dudley's Condensed Diagrams of part of Hudson Division, N. Y. C. & H. R. R. R.

that the rails were not stiff enough for the service, and after studying the diagrams for several thousand miles of track I designed the 5-inch 80-pound steel rail for the New York Central and Hudson River Railroad in April, 1883. With 23 per cent. more metal than was in their 4½-inch 65-pound rail, I increased the stiffness 66 per cent. The rail was rolled and put into service in 1884. This was the first 5-inch steel rail put into service in the United States.

Having noted the wear of the steel on all types of the heads of rails in the tracks, I made a broad head for stability and wear and a thinner head than usual for effective rolling, and balancing the section for better hot-bed treatment. This type of head has since become the prevailing type for modern vignole sections. The 5-inch 80-pound rail once in the track demonstrated the great value of stiffness in maintenance of way, and was followed by a number of sections of 5-inch 80 and 85-pound rails, by the leading railroad companies of this country.

The undulations in the track reduced to about four feet per mile on the first 5-inch 80-pound rails. The 5-inch 80-pound rails were all straightened at the mills on narrow-spaced supports used for much lighter rails, and were indented by the gag wherever applied, giving the surface a series of minute waves, the third form of permanent set, which makes from one to one and a half feet of the total sum of undulations found upon these rails per mile.

These rails never received proper hot-bed treatment, and the undulations in the surface increased the dynamic effects of the wheel loads, cutting out the ties, disturbing the ballast, beside giving a very unpleasant tremor to the cars when passing over them.

In 1883, after I had designed the 5-inch 80-pound rail, but before any were rolled and in the track, I calculated what I considered the possible condition of track for such rails would be when finished smooth, and put it on the condensed diagrams for that year. The results seemed so impossible that I was probably the only one for many years who expected to see them realized. Already they have been obtained on many railroads using rails of about the same type and stiffness for which the estimates were made, while with my stiffer sections still better results are obtained, as would be expected.

The value of stiffness in rails, in connection with sufficient

bearing surfaces for the wheel pressures and stability in reducing the undulations in the track, was shown to be so important by the first 80-pound rails in maintenance of way that in 1890, when designing my recent series of rail sections, I increased their stiffness per pound of metal, making them stiffer than any vignole sections which have been rolled in this country. They all have broad heads, which are essential during manufacture and subsequent service for smooth tracks and a high degree of stability.

A round, narrow-neaded rail rolls out gradually on the ties, widening the gauge of track, not being held in position by the wheel treads and wears rough.

The wheel treads on broad-headed rails reverse the case of the boy trying to lift himself by his boot straps and hold the rails in their vertical position on the ties, increasing their stability.

One of the strong objections urged against the introduction of higher and stiffer rails, "was the supposed increased tendency to roll out in the track." With properly designed heads the higher rails have been held in gauge much better than the former low rails.

I am now able to state quite definitely for each of my sections, according to their stiffness and traffic for which they are suited, the lower range of undulations per mile to which they may be reduced or maintained in the track, as shown by my track indicator.

For heavy branch-line traffic the 4⅝-inch 65-pound section, the undulations run down to 4 feet and 6 inches per mile, or the 31st line on the condensed diagrams. For the same kind of traffic the 5¾-inch 70-pound rails, 3 feet and 6 inches, or the 24th line on the condensed diagrams. The 5-inch 75-pound rails, heavy traffic 3 feet per mile, or the 21st line on the condensed diagrams. The 5⅛-inch 80-pound rails, three tie joints, under express trains 50 to 75 miles per hour, 2 feet 6 inches to 2 feet 9 inches per mile. The 18th line on the diagrams is taken as the standard. This section has an unexceptionable stability for the weight per yard.

The 6-inch 100-pound rails, three tie joints, the undulations run down to 1 foot and 6 inches to 2 feet per mile. As an all year round condition of track the stability being very high.

The figures given for the undulations per mile for each section are for rails without either the first or second form of permanent set in the track, the rails appearing in surface to the eye when not under trains.

I have designated such rails as the fourth or proper form representing the best condition of track for they are in perfect surface to the eye. (See cut No. 7.) The undulations which remain in the tracks under the figures given for each section are individually so minute at present they cannot be further reduced by the skilled trackmen.

The importance of knowing how low the undulations may be reduced in the track for each section of rail cannot be over estimated, for knowing what to expect, if not attained the reason why can be traced.

Each section of rail, like a locomotive of a certain class can only render a specific duty or permit a certain standard of track to be attained, for the deflections of the track decrease as the stiffness of the rails increases.

The weight of the locomotives and cars can only be transmitted to the rails through the wheel contacts, which produces a wave of general depression of the rails under the wheel base of the locomotive and cars, the greatest depressions and most intense waves of pressure being directly under the wheels.

To distribute the wheel loads to the ties, ballast and road-bed, the stresses of the metal in the rails under the wheels of the locomotives and cars become two kinds, viz.: compression in the head and tension in the base; while between the wheels the stresses are reversed, the head being in tension and the base in compression, the stresses reversing as each wheel passes over the rails; therefore only the ties in the general depression of the locomotive or cars are transmitting pressure to the ballast at the same time, while in the center of the space between the trucks the rails are not only relieved of pressure, but rise. The waves of pressure and relief may occur many times per second according to speed and length of train. See cut No. 30.

We can approximate the fibre stresses in rails in the track under static loads by placing a locomotive on them and measuring the elongation or compression per inch of the metal under stress. On 4½-inch rails, 16 ties per rail, a locomotive carrying 20,000 pounds per driver will show tension stresses under the drivers of 12,000 to 16,000 pounds per square inch, while those of compression between the wheels are usually about one-half to two-thirds as much. The figures are not uniform per rail length owing to unequal bearing of the ties.

On stiffer 5-inch rails the fibre stresses reduce to 5,000 pounds to 8,000 pounds in tension, and 4,000 pounds to 6,000 pounds in compression.

On the 6-inch 100-pound rails the highest in tension so far obtained are 4,000 pounds, and 3,000 pounds in compression.

These figures are, of course, only approximations under a given wheel bare of 8 feet and 6 inches for static loads. A shorter or longer wheel bare will give different results. Under moving loads they would be much higher, or for a poor condition of track. These figures of the stresses indicate that the dynamic effects from the wheel loads cannot become proportionaly as great on the stiffer rails as on the weaker rails, and this is shown by the experience of the past 15 years. While the wheel loads have all increased—that of the freight car having been trebled—the undulations in the track, by stiffer rails, have been reduced to one-third of their former amount.

The dynamic effects from the wheel loads have been reduced in a greater ratio, so that the combined static and dynamic effects of the heavier wheel loads as distributed through the stiffer rails per tie to the ballast and road-bed, are less than was the combined static and dynamic effects of the lighter wheel loads as distributed by the lighter rails per tie to the ballast and road-bed.

An unnecessary destructive force has been prevented from being generated and a great saving made in the cost of maintenance of way.

As may be inferred from cut No. 30 every tie underneath the lighter rails received its weight to distribute more in the nature of suddenly applied loads than gradual loads and its abrasion under the rails was very rapid.

As the cost of ties is now much greater than the cost of rail renewals, the saving in expense for ties will be quite an item in paying for stiffer rails.

Treated ties can now be used under the stiffer rails since the abrasion has been so much reduced.

The original diagrams on many tracks are quite smooth, being nearly straight lines on the heavy sections. (See cut 27.)

The difficulties of making rails increase rapidly as the sections increase in weight over 60 pounds, the composition and entire manufacture requiring special attention.

The hot-bed treatment becomes very important, so they will cool

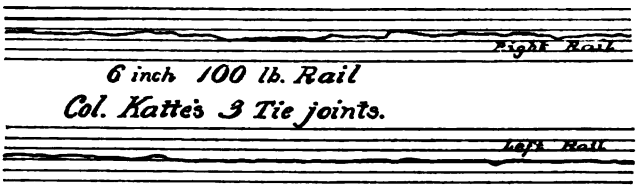


FIG. 27. Original diagrams of the surface undulations of 100-lb. Rails. Joints cannot be traced.

as nearly straight as possible, requiring but a little work under the straightening presses and be fairly smooth, and not filled with little waves by heavy gagging.

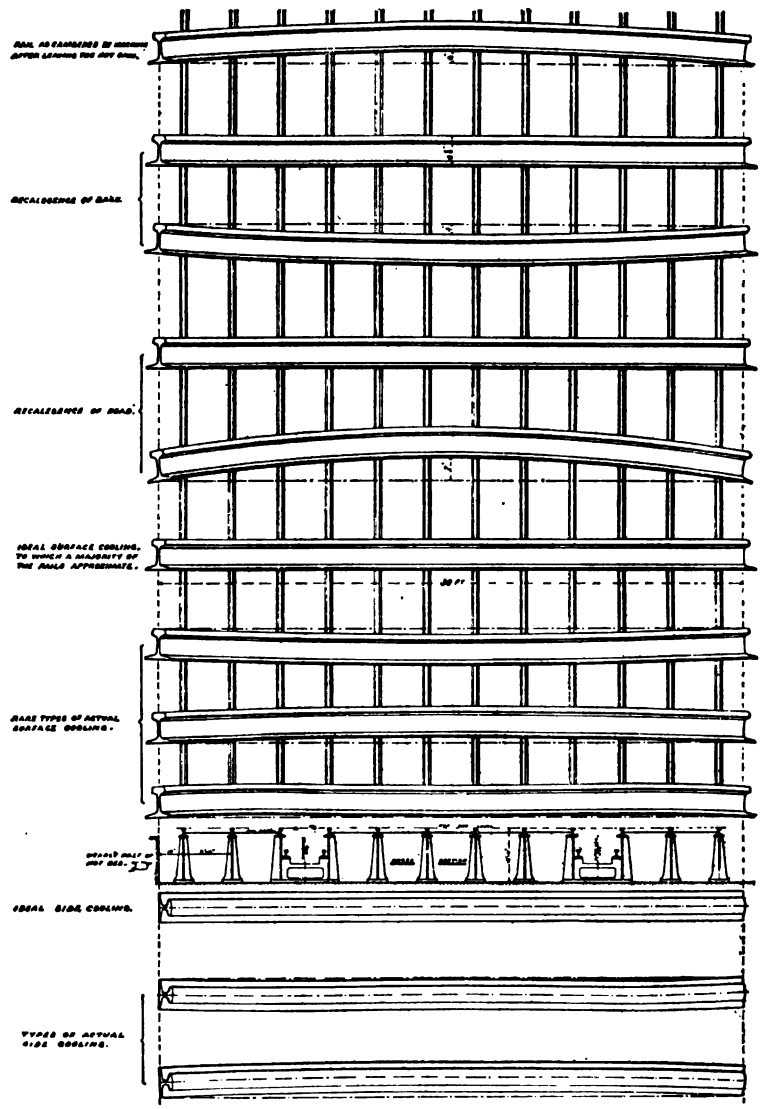
Cuts Nos. 28 and 29 show sections of a "Hot-bed" and the cooling of two types of rails.

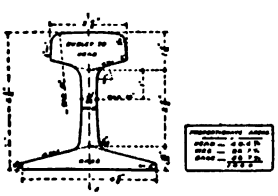
In the manufacture of rails, after they come from the "Hot-saws" and still white hot, they must be cambered, curving the head around the base so they will theoretically cool straight; then they go to the "Hot-beds" for cooling, where remarkable phenomena take place. In four or five minutes after the rails reach the hot-bed the base of the rail lessens its rate of cooling, straightens the rail, and then, in two or three minutes more, has curved slightly around the head, recalescence of the base. Then the recalescence of the head begins, restraightens the rail and continues curving the head around the base more than the original camber.

In about twenty-five to thirty minutes the gradual cooling commences to straighten the rail for the third time, which is practically complete in about forty to forty-five minutes.

The many movements of the rails while cooling, the friction on the rails of the hot-bed, render it impossible to cool the rails perfectly straight and smooth; they must still be straightened when cool under presses. To straighten the rails in the present presses, several blows are given the rail, and each must put a permanent set in the rail to be effective and show more or less afterward in the track.

Balancing the metal between the head and base, as it is in my sections, lessens the amount of camber required on the hot-bed, the rails come out straighter, which lessens also the amount of work required under the straightening presses. I have also widened the supports under the presses, the gags indenting the rails much less than on the short-spanned supports formerly used; and the rails came out smoother, with a better surface than is pos-

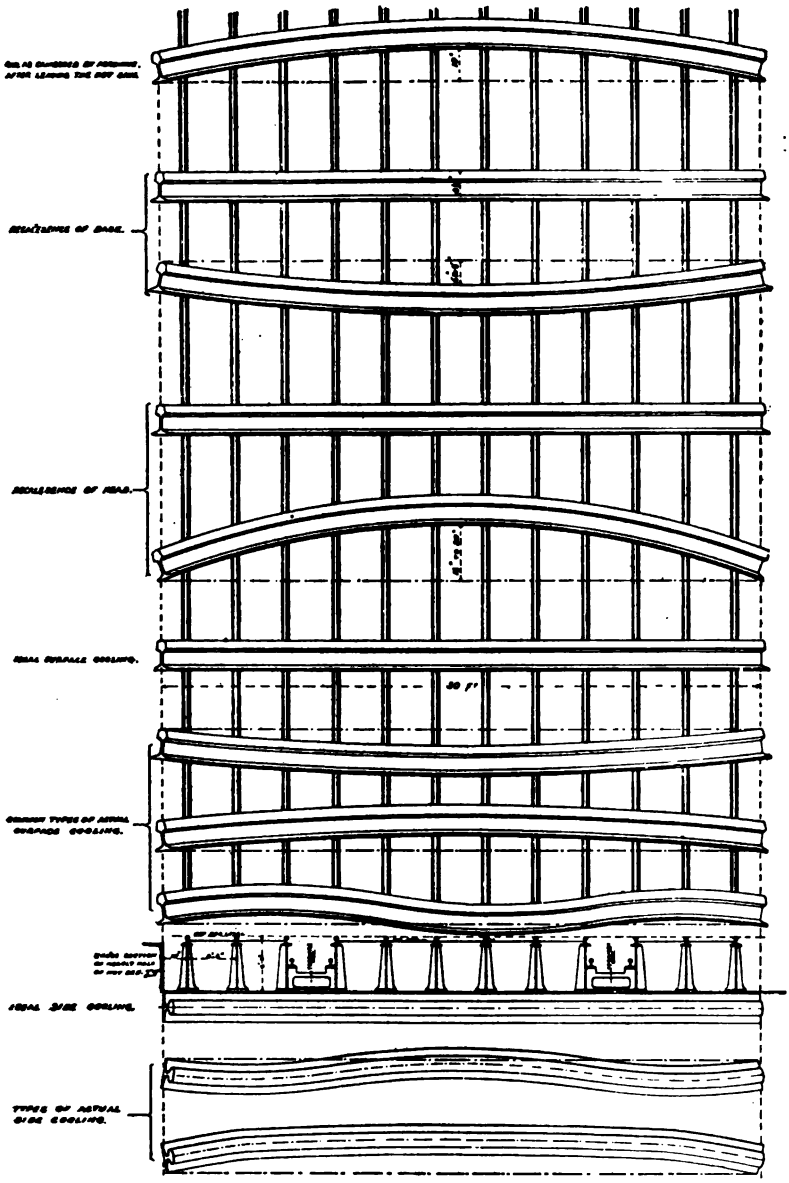

RECALESCENCE OF RAIL.
RECALESCENCE OF ROAD.
IDEAL SURFACE COOLING. TO WHICH A MAJORITY OF THE RAILS APPROXIMATE.
RAILS TYPES OF ACTUAL SURFACE COOLING.
IDEAL SIDE COOLING.
TYPES OF ACTUAL SIDE COOLING.

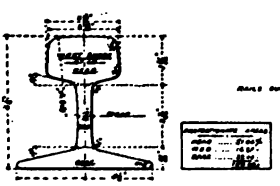


COOLING OF BALANCED RAIL SECTIONS ON THE HOT BED
RAILS SPACED 6 TO 8 INCHES APART.

CUT NO. 28.

P. H. DUDLEY, C.E.
60 PINE ST., NEW YORK





Cooling of unbalanced Rail sections on the Hot Bed.
Rails spaced 6 to 8 inches apart.

Cut No. 29.

P. H. Dudley, C.E.
60 Pine St., New York.

sible to obtain on unbalanced sections. The matters illustrated in cuts Nos. 28 and 29 will serve to show that the cooling and straightening of rails is a very difficult matter, and unless great care and attention are given to the rails during those processes the effects will appear when the rails are under traffic in the track, and become worse by service.

The center ordinates for 60-foot rails when cambered are four to five times that shown in the cuts for 30-foot rails, and for the long rails to go through all the movements in cooling on the hot-beds and come out fairly straight is an impossibility by present methods; besides, the long rails intensify the difficulties of straightening in a very marked degree, the practical results being that the 45- and 60-foot rails have not finished as smooth as the 30-foot lengths. The work must be improved, for 60-foot rails will be largely used in the future. Better methods for cooling and straightening all lengths of rails are desired, for the trackmen are now so skilled that they could surface perfect rails to true planes.

One of the great objects to be obtained in permanent way construction by the use of stiffer and smoother rails is, to prevent the dynamic effects of the moving wheel loads of either the locomotives or cars from reaching much magnitude, for the effects of the static loads, combined with the dynamic effects, when finally distributed to the road-bed, should always be less than its elasticity; otherwise the track cannot acquire any high degree of stability, nor be most economically maintained. The 5 and 6-inch rails are double and treble the stiffness of the 4½-inch rails, with much wider bearing surface for the wheels, and as would be expected, the diagrams show that the waves of pressure from the wheel loads must have been distributed over a much greater area of the road-bed, reducing their intensity to a factor more easily carried by the elasticity of the road-bed; which, although a very limited quantity, is a fundamental principle of maintenance of way. It has directly received too little attention, for many railroad people still treat the road-bed as though it were wholly an inelastic body, and permit the waves of pressure transmitted to it to be far in excess of its elasticity, and deformation takes place, which must be repaired at least by surfacing.

The elasticity of the road-bed is not likely to be uniform per mile for the entire road; some portions will take up and carry 3,000 pounds per square foot without injury, while other portions,

being more plastic, will not carry 2,000 pounds without set and deformation.

The drainage of the road-bed must be very efficient at all times, as a reduction of a few per cent. of moisture increases the plasticity and decreases the elasticity. The ballast under the ties when dry and of good quality is supposed to reduce the pressure from the tie to the road-bed, inversely as its depth. I think the estimate too high for general practice, and have shown the waves of pressure transmitted from the ties through the ballast to the road-bed as less in cut No. 30.

The condensed diagrams of a portion of the track on the Hudson division of the N. Y. C. & H. R. R. R., for 1895 and 1891, will convey a very definite idea of the reduction of the undulations in some tracks during the past 15 years. In 1881 when the first condensed diagrams of the condition of the track were made, 4 and 4½-inch 65-pound rails being in the track, the "condition of track on the diagrams ranged from the 50th to the 60th line.

The undulations of the rails on the original diagrams are fairly shown by the right half of cut No. 5.

In 1884 the first 5-inch 80-pound rail was put into service, and by 1891 the undulations in the track had been reduced one-half, which more than doubled the stability of the track.

The diagrams for 1895 show the greatest improvement of any yet obtained, and they are compared with those of 1891, instead of 1894, as those dates afford the most valuable comparisons between the stability of the track of different sections of rails; also comparisons between suspended joints and three tie-supported joints.

On the Hudson Division, in the diagrams for 1891, from New York to Mott Haven, the first 5-inch 80-pound rails laid in 1884, were still in service. They were laid with 22-inch splice bars, suspended joints, and replaced by 100-pound rails, in 1892.

From Spuyten Duyvil to Peekskill the 5-inch 80-pound rails were laid in 1886 and 1887, with 22-inch splice bars, suspended joints and were replaced by 100-pound rails in 1894. The condition of the track in 1891 on the 80-pound rails averaged some 8 lines higher than the track from Peekskill to Albany, laid with the 5-inch 80-pound rails and Col. Katte's three tie-supported joint.

From the condensed diagrams it will be seen that from Peeks-

kill to Albany the track has been maintained under its heavy traffic, practically on the same lines for four years—a result not probable with suspended joints.*

The 100-pound rail shows the highest possible condition, the undulations being reduced to the lowest limit which the trackmen can take up in surfacing, the original diagrams showing like Fig. No. 27. The 100-pound rail makes "Permanent Way."

On the condensed diagrams the "Condition of Track Line" for each inspection represents the average sum of *all* the various undulations of the rails per mile, as mechanically summed up by the inspection apparatus into feet and inches per mile.

To plot the sum of the undulations on the diagrams, the number of feet and inches per mile are reduced to inches and divided by 176, the number of 30-foot rails per mile, which gives the average undulations per rail per mile in hundredths of an inch. Each horizontal line on the diagrams represents one-hundredth of an inch; therefore as many above the base line are taken as the average hundredths of an inch of undulation per mile. The results for each track are relative to the base line, yet are comparative one mile with another.

The average condition of each mile is indicated from the horizontal line crossed or touched by the condition of track line in the center of the space for the mile.

The space between the vertical lines represents one mile of track.

Lines marked "Age of Steel" for each mile give its length of service, each horizontal line representing one year.

Lines marked "Percentage of Tangent and Curve" show the approximate alignment of both tracks per mile. The percentage of tangent is marked on the left side of the space for the mile, and that of the curvature on the right side. Each horizontal line represents 10 per cent. for the mile.

Lines marked "Profile" show the gradients of the road and are common to both tracks, though ascending grades on one track are descending upon the other and *vice versa*. Each horizontal line represents 10 feet of elevation and refers to the Base Line for track No. 1 in all cases.

* The condensed diagrams of the Hudson Division are only reproduced for 15 miles above Peekskill, on the 5-inch 80-pound rails. The balance of the distance to Albany is identical with that shown above Peekskill.

"Gauge of Track." Not a mile of track from New York to Buffalo, and return, was found one-tenth of an inch out of gauge, which eliminates that line from the diagrams.

"Side Irregularities of the Rails." This was reduced to the lowest possible limits and is omitted from the diagrams.

That not a mile of track was found out of gauge is a matter of great significance, for it shows, aside from the care which the track has received, that the stability of the broad-headed high rails is proportionally much greater, as was designed, than that of the low round-headed rails, and further that the larger locomotives, with high "center of gravity," are easier sidewise on the track than the older locomotives with low "center of gravity."*

THE OIL MACHINE.†

By GEORGE RICHMOND.

Probably ten thousand oil engines are at the present moment in operation in all parts of the world. This number is relatively very small and in explanation it must be remembered that the oil engine is practically a production of the present decade. Moreover the only suitable cycle was controlled by the owners of the "Otto" patents, who had no particular incentive to develop the oil engine. Apart from these facts the difficulties inherent in the use of oil were considerable, and the explosive engine could not be utilized until it had freed itself from certain limiting conditions.

This very quality of youthfulness should commend the oil engine to the favorable consideration of this Society. While disclaiming all pretension that the internal-combustion engine is destined to supplant the steam engine, it is very apparent that it will claim a large share of attention in the future. Now with the splendid facilities which you will have in the new University buildings, you will, no doubt, do very excellent work on the steam engine. The results will be almost entirely educational. You will do what

*The numbers of the cuts are the same as those on the series of Condensed Diagrams.

†One of a course of lectures delivered to the students of the Schools of Mines and Engineering, Columbia University, under the auspices of the Engineering Society.

some one else has done—nearly—as well, and you can hardly expect to see records of your work outside of your transactions. But the same care and diligence devoted to the oil engine could easily produce results which, while affording equally valuable training to the investigators, would, in the present dearth of data, cause the Columbia University to be quoted in all the text-books for the next twenty years at least. You will see that in the hope of securing your interest in my subject I do not hesitate to appeal to your pride in the Alma Mater.

It may interest you to know that while the oil engine has been developed abroad, the first engine which attained any degree of success was the invention of an American. Mr. Brayton, of Philadelphia, brought out his engine in 1873, and it was manufactured by the New York and New Jersey Ready-Motor Company.

In this engine there are two cylinders, one being a compressing pump and the other a motor. The charge of air is drawn into the pump on the out-stroke and compressed on the return into a receiver; the pressure usual in the receiver varies from 60 to 80 pounds per square inch above atmosphere. The motor cylinder takes its supply from the receiver, but the mixture is ignited as it enters, a grating arrangement preventing the return of the flame. Against this grating the oil was sprayed. The mixture, in fact, does not enter the motor cylinder at all; what enters it is a continuous flame. At a certain point the supply of flame is cut-off and the piston, moving on to the end of its stroke, expands the volume of hot gases to nearly atmospheric pressure before discharge. This engine worked fairly well, although its cycle is now obsolete, and its withdrawal from the market was chiefly due to the rapidity with which its cylinder sooted up.

For a long time the pilot flame method of ignition was exclusively used for igniting the charge in explosive engines, and while this practice lasted a successful oil engine was practically an impossibility. With the introduction of the hot-tube method and the revival of electric ignition, the use of oil became feasible, and accordingly the Priestman oil engine was brought out in 1888. This engine was exhibited at the Royal Agricultural Show in 1889 and created a very great interest among engineers, who immediately recognized its importcnce as a substitute for steam, especially on the farm, and for country houses, where gas is unobtainable. An immense impetus was given to the industry, and on the next

occasion of testing oil engines by the same Society, in 1894, no less than eight different oil engines were presented and all the honors were carried off by a new comer, namely, the "Hornsby-Akroyd." The oil engine was not regarded as a rival of the gas engine, but rather as extending the field of usefulness of explosive engines. That it should turn out to be a rather formidable rival of the gas engine is due to the fact that the fuel necessary to run it costs about half that of the corresponding amount of illuminating gas.

As a heat engine the oil engine enjoys—next to the gas engine (and following closely on its heels)—the distinction of converting into work a greater percentage of heat supplied to it than the best steam engine does. As you are aware, for each horse power produced by an engine, heat must be converted into work at the rate of 2545 units per hour. This number is thus obtained,

$$\frac{33000 \times 60}{778} = 2545.$$

Bearing in mind that this amount of heat corresponds roughly to about 2.3 pounds of steam, 0.3 pounds of coal, 4 cubic feet of illuminating gas or .13 pounds of oil, the following comparison may be made:

TABLE I.

One Horse-Power = 2545 B. T. U. Per Hour.

Efficiency.	Pounds Steam.	Pounds Coal.	Cubic Feet Gas.	Pounds Oil.
100%	2.3	.3	4	.13
2%	115	15	200	6.5
4%	57.5	7.5	100	3.25
8%	28.75	3.75	50	1.625
10%	23	3	40	1.3
15%	15.5	2	26.6	.87
20%	11.5	1.5	20	.65
28%	9 6	1.25	17	.54

	Mills.
Cost per pound of Coal at $4.00 per ton,	2
Cost of Gas per foot at $1.00 per 1,000,	1
Cost of Oil per pound at 7 cents per gallon,	10

Now the bulk of the steam engines in use, we may say practically all those below 40-horse-power, are included in the efficiencies below 10 per cent., which may be considered the lowest efficiency admissible for an internal combustion engine. On the

other hand, 28 per cent. efficiency has been attained by a simple half-single-acting explosive engine without much difficulty, and in view of the relative state of development it is apparent that the record will always remain with the explosive engine.

If these engines were equally efficient, the cost of fuel would show very largely in favor of the steam engine and it would have to plead its greater convenience to secure acceptance. I am frequently asked the question, "How does the cost for oil compare with the cost for coal," say on a 5-horse-power engine. When in return I ask, "How much coal do you expect to consume per horse power," I get an answer something like this, "Well nowadays 2 pounds is a common consumption, but let us say 3 or 4 if you like." I need hardly tell you that such enquiries do not come from members of the Columbia or any other Engineering Society. There does not appear to be any very reliable, or rather extensive, report on the fuel consumption of small engines. The following table,

TABLE II.

Coal Consumption Per Indicated H. P., in Small Engines.

Probable I. H. P., at full load. . 12	45	60	45	75	60	60
Average I. H. P., during observation. 2.96	7.37	8.2	8.6	23.64	19.08	20.08
Coal per I. H. P., per hour during observation, pounds . . . 36.0	21.25	22.61	18.13	11.68	9.53	8.50

taken from Professor Unwin's "Lectures on the Development and Transmission of Power," undoubtedly represents very bad practice and was intended to point a moral, namely, the advantage of distribution of power by compressed air. But it also represents facts which could be easily duplicated and are equally well adapted to adorn a tale of gas engines or oil engines. Another record, which, together with the last, is found in "Kent's Pocket Book," gives the result of trials of small engines at the Royal Agricultural Society Show in 1890, from which it appears that a 5-horse-power engine used 78.1 pounds of water and a 2-horse-power engine 89.9 pounds of water per horse-power. In both these cases the actual cost for coal is much greater than the actual cost for oil, and when we consider the time spent in getting up steam, keeping up steam, etc., it is probable that the claim that moderate sizes of

oil engines cost less than half the expense of running a steam engine of the same power is well founded.

Reference has been made to the difficulties inherent in the use of heavy safe oil. These difficulties relate to the vaporization and the ignition. Of three methods of attacking the first problem, in each of which a different method of ignition is used, a brief mention of the characteristics will suffice, since you can readily obtain a full description of these devices in the text-books.

Priestman's method, which, although not the most simple, is entitled to precedence for historic reasons. In this case the oil is sprayed into a chamber which is heated by passing the exhaust gas around it. The air for atomizing the oil spray is supplied by an auxiliary air pump, and the air required for combustion is all drawn through the vaporizer. The ignition is electric.

In the solution by Crossley and others, which became possible only by the production of a lamp adapted to burn kerosene without a wick, the ignition is by hot tube, and the waste heat from the flame, which plays around the tube, heats the flue, around which a spiral chamber is formed. A small quantity of air is drawn down this spiral passage, and the resulting heated current of air meets the oil which is injected by a pump into the lower part of the vaporizer. The hot air saturated with oil vapor is drawn through a valve into the cylinder, and the additional air required for combustion enters the cylinder through another valve.

In a unique solution of both problems known as the "Hornsby-Akroyd method," the separate vaporizer and the ignition device are both dispensed with. A portion of the cylinder connecting with the rest by a narrow neck is unjacketed and, therefore, remains at a temperature approaching a dull red heat; oil only is injected into this extension, which is in effect the vaporizer, and air only is drawn into the cylinder. Neither of these are explosive, and the explosive mixture is formed by forcing the air through the neck into the vaporizer on the return of the piston. The ignition takes place at the end of the compression stroke. This very beautiful solution of both problems at once makes the oil engine simpler than either the gas engine or the steam engine.

Let us turn now for a brief survey of the principles involved in this heat engine. The distinctive names of the various heat engines refer to the agents used rather than to the principles involved. The oil engine differs from the gasoline engines in that it uses a

grade of oil which cannot be vaporized by passing air through it or injecting it into a moderately warm cylinder. The gasoline and oil engines differ from the gas engine in that they manufacture their own gas, but all of these engines are simply hot-air engines. The theory of the action is substantially the same as that of the better-known steam engine. We may consider that air instead of water is pumped into the boiler and that each cylinder charge is heated (after being shut off from the boiler) to the required temperature by combustion in the cylinder. We perceive at once an obvious advantage in performing the combustion within the cylinder, since the loss of heat in the chimney is eliminated.

We have seen that when the ratio $\frac{H_1-H_2}{H_1}$ is applied, the internal combustion engine comes out very much ahead of the average steam engine. There is another ratio which you will readily recognize, viz: $\frac{T_1-T_2}{T_1}$ in which T_1 is the temperature at which the heat is supplied to the engine and T_2 the temperature of the rejected heat. For the perfect heat engine working on the "Carnot" cycle these two ratios are equal, but for any practical engine the first one, termed the actual efficiency, is smaller than the second, termed the ideal efficiency.

In the case of the steam engine the actual efficiency is about half the ideal efficiency, while for the internal combustion engine it rarely reaches one-fourth. From these facts two inferences are frequently drawn, the one of which seems to afford a certain amount of satisfaction to writers on the steam engine, while the other encourages expectations on the part of the partisan of the explosive engine that are entirely illusory. For it would seem that as an appliance for converting heat into work the internal combustion engine is very inferior to the steam engine, and as a corollary to this, that the margin for improvement in the former case is much larger than in the latter.

In order to see the exact significance of these statements it will be necessary to go briefly over ground which is perfectly familiar to those who have attended the lectures on thermodynamics, and the matter is really so simple that it will readily be understood by all.

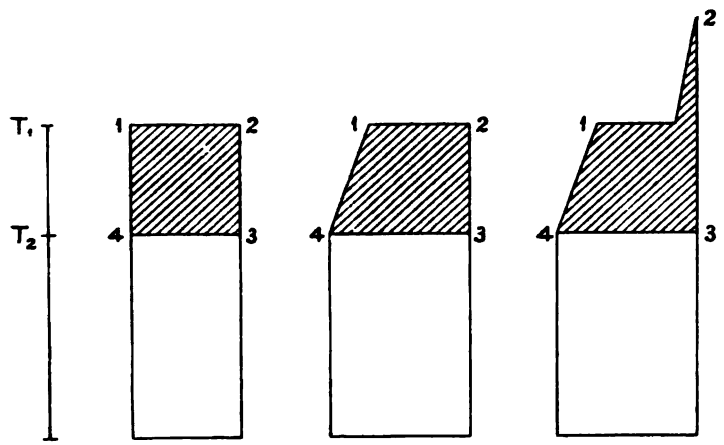


Fig. 4 Fig. 5 Fig. 6 Fig. 7

If we set up a line representing T_1 (Fig. 4) on any convenient scale, and cut off a portion equal to T_2, the line is evidently divided in the ratio $\frac{T_1 - T_2}{T_1}$ and rectangles on these lines will have the same ratio. If the rectangle on T_1 represents the heat supplied to an engine, that on T_2 will represent the rejected heat and their difference, namely, the rectangle 1, 2, 3, 4 (Fig. 5) will represent the amount of heat disappearing by conversion into work.

Moreover, by following this rectangle around, we read off the physical changes undergone by the agent used, which are, of course, precisely those required for the "Carnot" cycle. In traveling from 1 to 2 the ordinate representing temperature remains at constant height and sweeps out an area representing *the heat imparted at constant temperature.* From 2 to 3 the temperature is reduced without addition or removal of heat, representing *adiabatic expansion.* From 3 to 4 the ordinate sweeps out the area of *heat rejected at constant temperature* by traveling to the left. From 4 to 1 the agent is raised in temperature without addition or removal of heat, thus representing the *adiabatic compression* necessary to bring the agent to its initial condition. As a result of this process the shaded surface is traced, which represents the missing heat $H_1 - H_2$, and its area expressed in foot pounds is precisely the same as that which would have been traced by the indicator.

The indicator diagram is an autographic record of the work done, and although we cannot obtain an autographic record of the heat changes, we can readily construct the diagram representing them when they are known. For example, the cycle of the steam engine differs from the ideal cycle just considered chiefly, in the fact that the temperature T_1 is not reached by compression of the partially condensed steam, but by the addition of heat to water.

This heat is added at constantly rising temperature and is represented by the area swept out by the ordinate travelling from 4 to 1 (Fig. 6). The rest of the cycle is theoretically the same, and it is apparent that the ratio of the shaded area representing the transformed heat $H_1 - H_2$, to the total heat imparted H_1, does not differ very materially from that of the ideal cycle. The fact that in the steam engine the heat actually transformed is little more than half this amount indicates that the actual heat graph representing the physical changes is considerably modified in practice. It would be entirely foreign to our purpose to follow up these modifications in which, as you know, the cylinder walls play a large part.

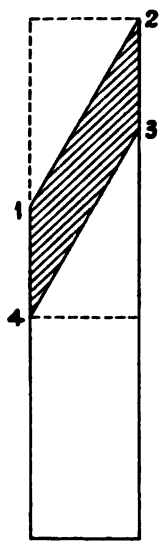


Fig. 8

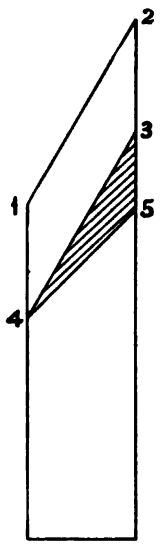


Fig. 9

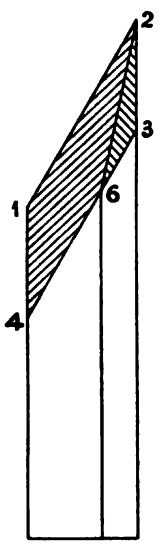


Fig. 10

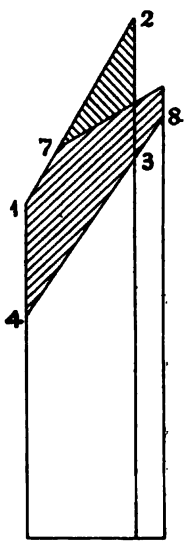


Fig. 11

In Figure 7 we have the heat graph when the steam is superheated. In this case, after vaporization has been completed at 2,

further addition of heat causes a rapid rise in temperature, the curve from 2 to 2^1 being much steeper than that from 4 to 1, since addition of equal quantities of heat increases the temperature of steam nearly twice as much as that of water.

In this case, if we take 2^1 as the highest temperature, the ratio $\frac{H_1-H_2}{H_1}$ will be very much smaller than the ratio $\frac{T_1-T_2}{T_2}$ and the introduction of a material improvement in the steam engine may result in an apparent diminished relative efficiency. From this it is apparent that the relative efficiency obtained by comparison with the "Carnot" cycle conveys very little information as to the real efficiency of the engine or the possibilities and conditions of improvement. If, however, we make a graph of the heat changes we obtain a closed area corresponding to the indicator diagram and representing the maximum amount of convertible heat for that particular cycle. More than this we see clearly what changes in the cycle are necessary to increase this area for a given amount of supplied heat.

There are thus at least three efficiencies:

(1) *The actual* represented by the value of the ratio $\frac{H_1-H_2}{H}$ experimentally determined.

(2) *The ideal* represented by the ratio $\frac{T-T_2}{T_1}$

(3) *The possible*, represented by the maximum area enclosed by the heat graph of the cycle employed.

In the oil engine the first has a value ranging from 10% to 18%, the second varies from 65% to 80%, while the third has a range of from 30% to 40% only. By comparing the first and third of these it will be seen that the oil engine is little, if at all, inferior to the steam engine, and that any material increase in efficiency must require a modification of the cycle in use, making it conform more closely to the ideal cycle.

You will have noticed that in the heat diagram the ordinates represent absolute temperature, but no name has been given to the abcissas. These, of course, indicate entropy, and the diagram is simply a graphical representation of the second law of thermody-

namics, embodied in the expression dH=TdS, just as dW=PdV is represented by the indicator diagram.

Moreover, for perfect gases the relation between these pairs of coördinates are very simple and we pass readily from one to the other. On the temperature entropy diagram all the lines required for an elementary study of the subject are either straight lines or definite curves that can be cut out once for all. Adiabatics and isothermals are obviously vertical and horizontal lines respectively, and it can very easily be shown that when the temperature ordinate sweeps out an area proportional to the rise in the temperature (which is the case when the specific heat is constant) its extremity will describe a logarithmic curve.

In the case of an oil engine on the "Otto" cycle the highest temperature is reached partly by compression and partly by the addition of heat by combustion at constant volume. In Figure 8 compression raises the temperature from 4 to 1; and 1 to 2 marks the rise in temperature in consequence of the addition of heat at constant volume, the amount of which is represented by the area swept out by the vertical line in traveling from 1 to 2. From 2 to 3 the temperature is reduced without addition or removal of heat (adiabatic expansion). The expansion is continued until the initial volume is reached, or the point 3 lies upon a line of constant volume drawn through 4. The shaded area, as in the previous case, represents the total amount of heat which it is possible to convert into work in the "Otto" cycle. If we draw horizontal lines through the points 2 to 4 we obtain the rectangle representing the available heat for an ideal engine working between the same temperature 2 and 4. The difference between these areas indicates very clearly the absurdity of applying the "Carnot" ratio to the "Otto" cycle engine. All the facts and possibilities of this cycle can be read at a glance from this figure. It is obvious that the efficiency is proportional, not to the difference between the highest and lowest temperatures, 2 and 4, but to the difference between the temperatures produced by compression (1) and the initial temperature 4. From this it follows that the efficiency of the theoretical "Otto" cycle can be increased to any desired degree by increasing the compression. It does not, of course, follow that this would be true in actual practice.

The gain by complete expansion is seen in Figure 9. The expansion, instead of stopping at the point 3, is continued till the at

mospheric pressure is reached. At the point 4 the gas is also at atmospheric pressure, and a line of equal pressure drawn through this point will be less steep than the line 4–3, since the specific heat of air at constant pressure is greater than at the constant volume. This line will cut the vertical, 2–3, at the point 5, and the additional work obtained by complete expansion is that represented by the triangle, 4–3–5. Not only is the available heat of the oil engine much less than that of the ideal engine of similar range, but it is further diminished by two circumstances, the one physical and easily understood, the other chemical and somewhat obscure. The temperature obtaining in the oil engine would make the cylinder nearly, or quite, red-hot and render proper lubrication impossible. Hence the necessity of the water jacket, which carries away nearly one-half of the total heat supplied to the engine. This involves a great sacrifice of the available energy, but if the water jacket were suppressed the greater part of the heat it eliminates would go into the exhaust.

The action of the water jacket may be seen in Figure 10. During expansion heat is removed to an amount represented by the area swept out by the vertical in travelling to the left from 2 to 6. The area of available energy is diminished by the triangle, 2–3–6, and the exhaust heat is diminished by the area swept out by travelling from 3 to 6. This latter quantity of heat belongs to the exhaust or rejected heat, and it is immaterial whether it passes out in the jacket or the exhaust.

The sum of these two does not represent the fifty per cent. of jacket heat, for a large part of this is taken up during the exhaust stroke. The point 6 can be determined when the final temperature or pressure of expansion is known and the two areas in question would be ascertained with sufficient accuracy by drawing a straight line from 2 to 6. On the indicator diagram this represents an expansion line considerably below the adiabatic curve. But the second circumstance has an opposite effect, and the combination generally results in throwing the actual expansion line above the adiabatic. The reference here is to be retarded combustion. It is found that at the moment of ignition the theoretical temperature 2 of Figure 8 is not obtained and, consequently, only the heat due to partial combustion is applied along the line, 1–2, the remainder being added during the expansion. Figure 11 represents this phenomenon; the first ignition supplies heat from

1 to 7, and the expansion line is carried out of the vertical over to 8, by the subsequent addition of heat. If the area by the path 1–7–8 is the same as that from 1 to 2, the combustion is compleled at the end of the stroke. If it is less, then unconsumed oil is passed out with the exhaust. The positions of both the points 7 and 8 depend on a variety of circumstances, the most important being the proportion of oil to air at the time of ignition.

In order to trace heat changes corresponding to an actual diagram it is necessary to establish the relations between P. V. T. and S. The two equations :

$$PV = RT$$
$$S = n \log_e P + m \log_e V,$$

where m and n are the specific heats at constant pressure and volume respectively, enable us to pass readily from the one system to the other. An actual indicator diagram from a "Hornsby-Akroyd" engine is given below and the value of T and S have been calculated for ten points on the curve K.

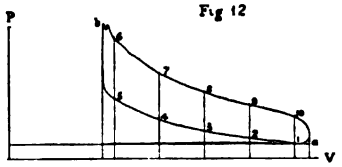


Fig 12

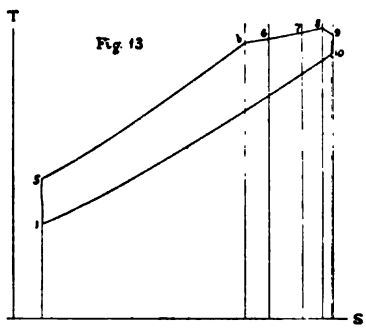


Fig 13

TABLE III.

	P. V.	T. /T.	.176 Logp+246 Log. v.	S–S.
1	475	1.000	6,094	
2	545	1.147	6,149	55
3	600	1.263	6,159	10
4	661	1.391	6,154	– 5
5	706	1.486	6,095	– 59
			.189 Logp+.26 Log. v.	
b	1,391	2.928	6,943	854
6	1,404	2.956	7,045	102
7	1,438	3 027	7,183	138
8	1,460	3.073	7,268	85
9	1,428	3.006	7,313	45
10	1,300	2.800	7,308	· 5

Some uncertainty attaches itself to the values to be assigned to m and n. By a process of approximation, usual in this connection, and which cannot be very far from true, the value of m has been taken at .246 on the compression curve and .26 on the expansion curve, while n is taken at .176 for the compression and .189 for the expansion curve. One of the conveniences of this method of tracing the heat changes is the fact that we can draw our diagram to any convenient scale without assuming any value for T. When subsequently a value is either ascertained by experiment or assigned, the scale of T may be written down. The same diagram will, of course, serve for any other value of T by simply noting the change of scale.

In the same manner ordinary logarithms may be used in calculating the value of S and any convenient scale in plotting the results and for numerical results the actual value of the entropy scale can be readily ascertained. From the table it is evident the compression curve is practically an adiabatic, the slight accession of heat from the warm cylinder sides during the commencement of the stroke being compensated for by the rejection during the latter portion of the stroke and both being too small to be shown on the heat diagram on the scale used. On the expansion curve, while the bulk of the heat is added at the moment of ignition, the combustion is evidently continued to nearly the end of the stroke. The heat due to this retarded combustion is really greater than the figures indicate, since during this time heat has been escaping through the walls of the cylinder. The time at our disposal precludes any further discussion of this subject, the brief outline of which must be considered as suggestive only.

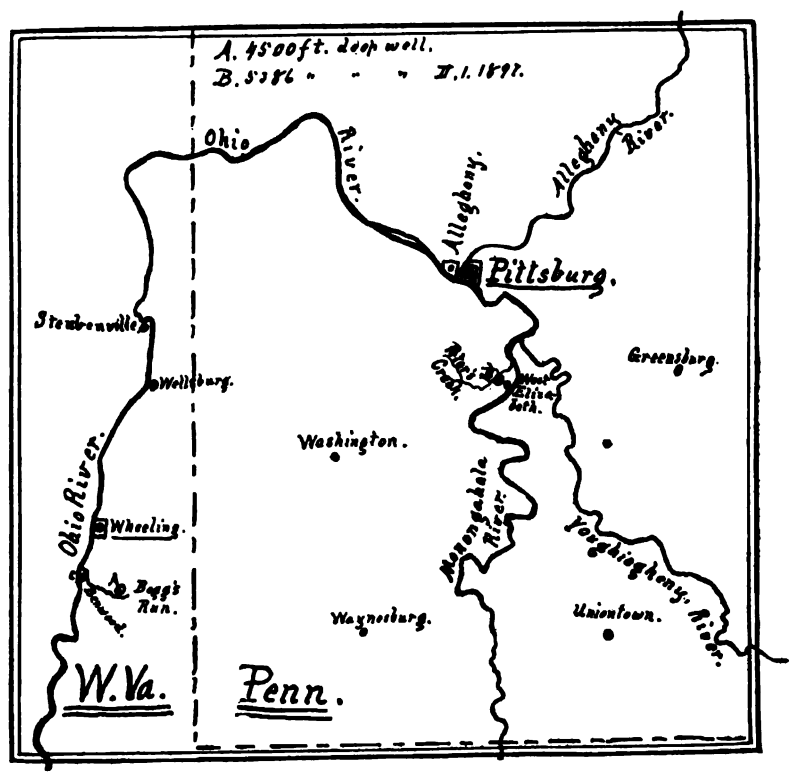
In conclusion some explanation is due to you of my apparent trespressing on the subject of the class room rather than confining myself to the practical application of the oil engine, as you might have expected. But I am so closely identified with a certain oil engine and my convictions on the subject are so strong that I felt it would be impossible to do full justice to the claims of others. I have chosen, therefore, a neutral ground, and I think it is not altogether inappropriate to call your attention to a graphical method of studying the oil engine, which, like the engine itself, originated in this country and, like it, has been developed chiefly abroad.

SUBTERRANEAN TEMPERATURES AT WHEELING, W. VA., AND PITTSBURG, PA.

By W. HALLOCK.

The question as to the conditions which exist in the interior of the earth has always attracted much attention. The most important factor in the solution of this riddle is the determination or estimation of the temperatures there existing. The British Association has for years seized every opportunity to obtain data as to the rate at which the temperature increases as the earth's crust is penetrated. Some of the most recent and reliable contributions on this subject are by Mr. E. Dunker, of Halle, Germany, and were obtained from a 4,170-foot well at Sperenberg, not far from Berlin, and a 5,740-foot well at Schladabach, near Leipzig.

Early in 1891 a number of the most enterprising citizens of Wheeling, under the name of The Wheeling Development Co.,



finished a well near Wheeling, on Bogg's Run, on the farm of Squire Keltz. This well was 4,500 feet deep, 4⅞ inches diameter and *dry;* cased only to 1,570 feet. The strata there are nearly *in situ*, undistorted and dipping only fifty feet to the mile. More satisfactory geological conditions can scarcely be imagined.

The well being dry, ordinary U. S. Signal Service maximum thermometers were used, and special tests showed that no precautions needed to be taken to prevent circulation of the air. The thermometers were lowered and raised, and depths measured by a steel wire.

Results:

TABLE I.

DEPTH FEET.	TEMP. FAHR.	DEPTH FEET.	TEMP. FAHR.
1350	68°.75	3125	88°.40
1591	70 .15	3232	89 .75
1592	70 .25	3375	92 .10
1745	71 .70	3482	93 .60
1835	72 .80	3625	96 .10
2125	76 .25	3730	97 .55
2236	77 .40	3875	100 .05
2375	79 .20	3980	101 .75
2486	80 .50	4125	104 .10
2625	82 .20	4200	105 .55
2740	83 .65	4375	108 .40
2875	85 .45	4462	110 .15
2990	86 .60		
		100	51°.30

These observations when plotted show a slow increase for the upper half of the uncased portion, about 1° F. for 80 to 90 feet, whereas the lower part shows a more rapid increase, about 1° F. for 60 feet; the whole series giving a well-defined and regular curve, with a slight deflection at 2,900 to 3,000 feet where oil sand occurs. Practically all the rest of the uncased well is in shale. The increase in the rate at which the temperature rises as the bottom is approached can only be temporary or we should have an inconceivable or improbable state of temperature at comparatively slight depths.

The two distinct series of observations combined in Table I. nowhere disagree more than 0°.3 F. and hence may be looked upon as very reliable and accurate.

Table II. gives a comparison of the results at the four great wells.

TABLE II.

NAME OF WELL AND LOCATION.	FEET FOR 1° FAHR.	TOTAL DEPTH.	TEMPERATURE AT TOP.	TEMPERATURE AT BOTTOM.
Sperenberg, near Berlin	59.2 ft.	4170 ft.	47°.8 Fahr.	1180.6 Fahr.
Schladabach, near Leipzig	65.0	5740	51 .9	135 .5
Wheeling Development Co.				
Top and greatest depths	74.3	4500	51 .3	110 .3
Mean of lower 3,000 feet	75.4			
Pittsburg, Peter's Creek	71.5 { to 5000 ft	5386	51 .0 (?)	{ at 5,000 ft. 120°.9

A series of observations in a coal mine near the well gave as a *very* probable value of the temperature of the top invariable stratum 51°.3 Fahr. From the mean annual temperature of Marietta and Steubenville as reduced by Schott it might be taken at 51°.5 Fahr.

Samples of air were taken at the bottom of the well, but their subsequent analysis revealed nothing of especial interest.

This well was drilled by T. S. Kinsey and his two sons, of Wellsburg, W. Va.

When the observations of 1891 were finished, an oak plug was driven into the top of the casing and thus the hole protected. In July, 1893, the hole was opened, and it was found full of fresh water to within forty feet of the top, having leaked full in something less than two years. Those who should know have no doubt that this water has entered at the lower end of the inner casing, *i. e.*, at 1,570 feet below the surface.

It was very desirable to obtaining a series of temperatures with the water in the well, to discover the extent to which its circulalation would or does affect the distribution of temperature in the hole.

The ordinary signal service mercurial maximum thermometers were used, inverted, as in 1891. They were enclosed in a heavy, sealed glass tube to protect them from the pressure of the water, and were used in pairs and *all* corrections applied. The two always agreed within 0°.2 F., except once at 2,669 feet, when one evidently failed to record correctly. Two thermometers were in an iron bucket, three feet long and three inches in diameter at the end of the wire, and two were in an open wire frame, two hundred and sixty feet from the end of the wire. The temperatures at depths of one, two and three hundred feet were determined with other thermometers separately lowered from the top of the well.

The results are given in Table III. The first column contains the depths in feet; the second, the corresponding temperatures in degrees Fahrenheit, as they were found July, 1893. In column three are the temperatures interpolated from Table I., as found in July, 1891. The last column gives the differences, or rise in temperature, in the well in two years.

At 3,200 feet an obstruction occurs, which I was not able to remove with the available tools, and which temporarily prevented an investigation of the lower 1,300 feet of the well. A glance at the fourth column in Table III., shows that the temperatures in water in 1893 are practically identical with those in air in 1891.

TABLE III.

Depth in feet.	Temperatures in Fahrenheit.		1893. mims. 1891.
	1893.	Interpolated from 1891.	
103	52°.53*	.....	.....
206	53.53	.....	.....
311	55 03	.....	.....
1586	70.12	70°.15	—0°.03
1921	73.95	73.82	+.13
2055	75.28	75.42	—.14
2276	78.13	77.93	+.20
2396	79.54	79 45	0 09
2539	81.21	81.15	0.06
2669	83.39†	82.75	0.64†
2793	84.56	84.41	0.15
2937	86.12	86.07	0.05
3057	87.42	87.50	—.08
3196	89.27	89.30	—.03

Only once does the difference amount to 0°2. Fahrenheit, and these differences show no evidence of a warming in the top and cooling in the bottom, as we would naturally expect. It seems to me we are thus compelled to believe that there is not an appreciable circulation even of water in a hole of five inches diameter.

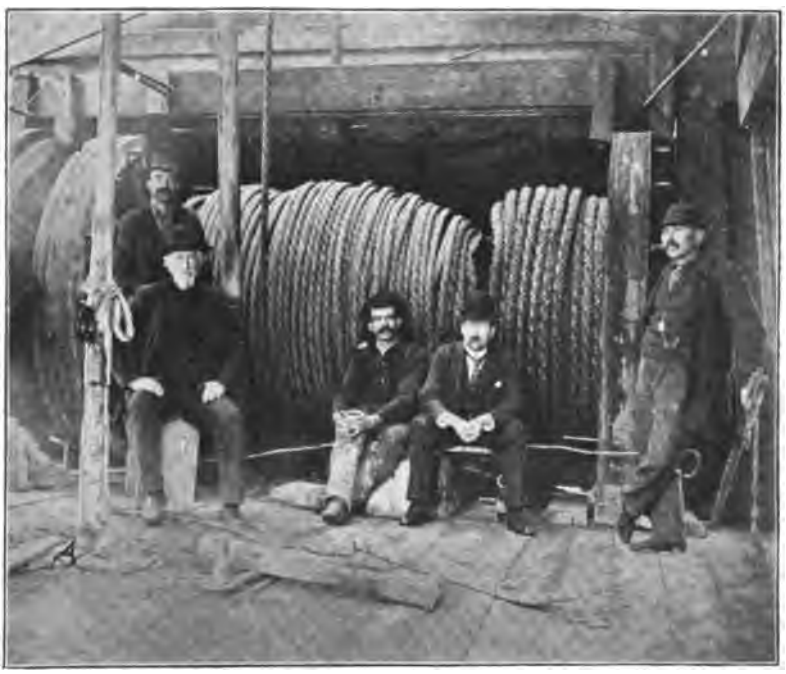
The Forest Oil Company, of Pittsburg, Pa., are at present at work upon a well which is already the deepest on this continent and the third in the world, and will be raised to the second place if care and enterprise can do it. It is already the deepest ever drilled with a cable, its rivals in East Prussia having been put down with rotating diamond core drills. The well, in February,

* Probable temperature at one hundred feet, from other observations, 51°.30.

† Or more probably, 82°.87 and +0°.12.

1897, is 5,386 feet deep, about 6⅛ inches in diameter of casing, which is only a little over 900 feet in depth. The well is dry and has an inlet of gas at a depth of 2,285 feet.

The geological conditions of this well are almost identical with those at Wheeling. The well is on Peter's Creek, on the farm of Wm. Bedell, about 2½ miles west of West Elizabeth and about 12 miles south south-east of Pittsburg.



Mr. Young, the vice-president and manager of the Forest Oil Company, has very kindly consented to the use of the well for the investigation of the underground temperatures at that place, and hence we have here a rare chance for obtaining more data as to the interesting question of earth temperatures.

Mr. E. E. Crocker, the superintendent of that section, went with me to the well and was of the greatest assistance, both with advice and hands. The drillers also contributed in a large degree to the ease and success of the expedition. It is indeed gratifying to find "practical men" so interested in scientific questions and so willing to put up with what to them must appear as useless trifles. The

actual work at the well is in the hands of S. W. Colman, H. A. Stroup, Clif. Young and Eugen O'Brian; Mr. Kegan having direct supervision of the wells in that particular district. It would be difficult to find a lot of men better quallified to "break the record," and carry this well to its utmost depth.

The thermometers were lowered upon a steel tape marked every 50 feet, which was wound up upon a spool attached to the shaft of the engine.

A pair of readings were made at 2,250 and 2,350 feet, *i. e.*, just above and just below the inlet of gas. The reading at 2,350 feet was about 78° Fahrenheit, which agrees well with the same depth at Wheeling, but the thermometers could not be left down long enough to give a thoroughly satisfactory reading. The thermometers at 2,250 feet indicated a cooling due to the expansion of the gas amounting to about 14°.

Four thermometors were lowered to a depth of 5,000 feet at 5 P. M. on the 5th of February and taken out at 9 A. M. on the 6th; they gave a record at that depth of 120.9°. This means a temperature of about 127° at the bottom, 5,386 feet below the surface of the earth.

A careful comparison of this record with the Wheeling temperatures will show that the two are almost identical for the same depths; for example, exterpolating from the Wheeling well to 5,000 feet we get 119.6° as against 120.9° at Pittsburg.

Science is indebted to Professor I. C. White for the diversion of the Wheeling and Pittsburg wells into scientific channels, and the U. S. Geological Survey has generously contributed toward the payment of the expenses incident to these investigations.

In the late spring or early summer it is hoped that a fuller record of the temperatures in the well can be obtained.

The well which stands without a peer on earth is at Paruschowitz, near Reibnik, in Eestern Silesia. More than two years ago it was over 6,500 feet deep, and it was the intention to go about 8,800 feet (2,700 meters). No recent report has been had from it, and temperature observations were not to be commenced until the well was finished. We may, however, rely upon the Germans to give us a thorough and trustworthy record, when the time comes.

DETAILS OF MODERN WATER WORKS CONSTRUCTION.*

By WOLCOTT C. FOSTER.

Part V. Service Connections; Tapping Machines.

Service Connections. The branch pipes leading from the street mains into the buildings of consumers are usually termed "service connections," "service pipes" or "services." The size of the connecting pipe depends, of course, upon the probable consumption of water. For ordinary household use pipe is generally from ½ inch to ¾ inch in diameter. For mills, factories, etc., it may sum up as high as 8 inches or larger, though this is exceptional. The large services are connected with the mains by a special, small services by a corporation cock, described in Part III., Vol. XVI., p. 140. The material generally used for small service connections is either galvanized iron or lead pipe, though other kinds of pipe have been used to a greater or lesser extent, such as tin-lined lead pipe, lead-lined iron pipe, cement-lined pipe, rustless-iron pipe or pipe treated so that the surfaces are covered with the black oxide, tarred pipe, etc. When galvanized-iron pipe is used it is well to make the connection between the main and the cellar wall as shown in Fig. 75. First the corporation-cock is screwed

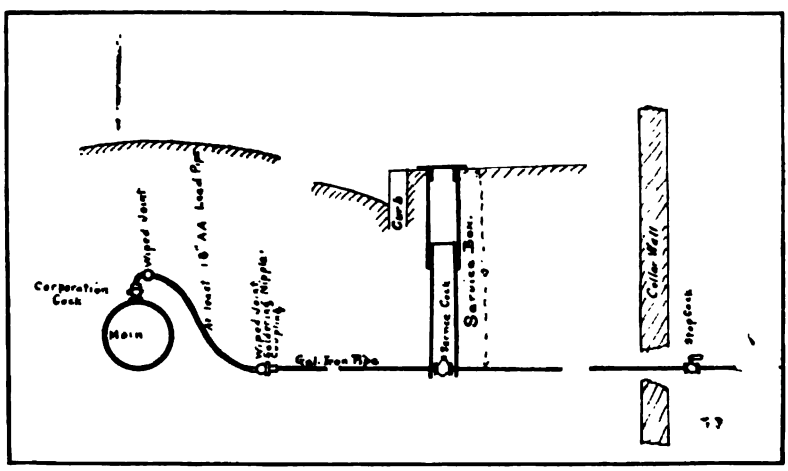


Fig. 75. Service Pipe Connection.

*Copyright, 1897, by W. C. Foster.

into the top of the main or the side near the top. This is connected by means of a union and "wiped-joint" with a short length of lead pipe, to the other end of which is attached a soldering nipple by a second "wiped-joint." This short piece of lead pipe is known as a "goose-neck" and is shown enlarged in Fig. 76.

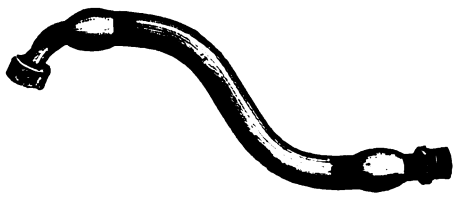


FIG. 76. Goose Neck.

Goose-necks with soldering nipples and couplings attached can be purchased ready-made. The free end of the soldering nipple is threaded and is connected with the iron pipe by a coupling. At the curb the iron pipe is cut and a service cock (Part III., Vol. XVI., p. 140) inserted. The service-cock is protected by a cast-iron service-box. This cock is inserted for convenience in controlling the water supply to the consumer. In case of a leak in the house, or in case it is desired to stop the supply for the non-payment of rent or other reason, the water can be shut off at this point. Just inside the cellar wall a stop-cock, Fig. 77, with a waste vent draining the pipes in the house should be

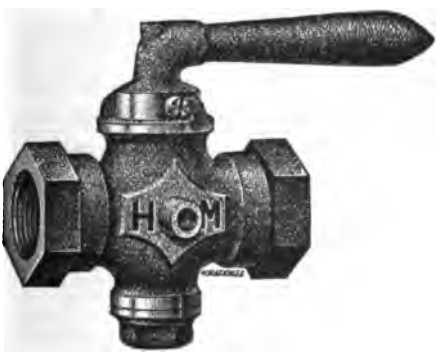


FIG. 77. Stop Cock With Waste.

placed. When meters are used the arrangement shown in Fig. 78 for use inside the cellar is a very good one. When it is necessary to make a comparatively large service connection, such as 1½ inch or 2 inch, the connection with the main may be made

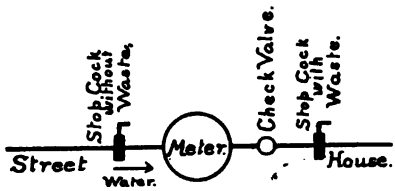


FIG. 78. Meter Service.

either with a single tap or by a manifold and several smaller taps, always bearing in mind that the areas of pipes are proportional to the squares of their diameters, in finding the number of taps to use. Thus supposing it is desired to connect a 2-inch service pipe with the main by taps having a clear area of ¾ inch, then 2 inch or $\frac{8}{4}$ squared = $\frac{64}{16}$ and $\frac{3}{4}$ squared = $\frac{9}{16}$, then $\frac{64}{9} = 7\frac{1}{9}$ or 8 $\frac{3}{4}$-inch taps. Each tap should be connected with the manifold by a goose-neck, and it is advisable to put the taps in the main spirally. The manifold may be made up of T's and short nipples, as in Fig. 79.

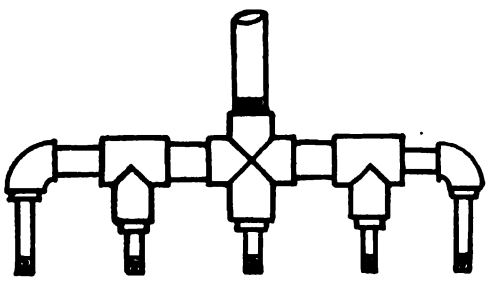


FIG. 79. Made-up Manifold.

Or instead of using a made-up manifold a specially manufactured manifold may be employed. These manifolds are of brass for use with either iron or lead pipe and the following sizes are kept in stock:

TABLE X.—STOCK MANIFOLDS.

Trade No. of Manifold.	Diameter of Service Pipe. Inches.	No. of Branches for 1-in. taps.	Nature of goose neck connection with Manifold.	Nature of Service-pipe Connection.
1	1¼	2	Wiped joint	Wiped joint
2	1½	3	" "	" "
3	2	4	" "	" "
4	1¼	2	Soldering union	" "
5	1½	3	" "	" "
6	2	4	" "	" "
7	2½	6	Wiped joint	Screw joint
8	3	8	" "	" "
9	2½	6	Soldering union	" "
10	3	8	" "	" "

The manifolds are designed with a view to using 1-inch corporation cocks for connecting with the main. Fig. 80 shows a

FIG. 80. No. 8 Manifold Connected With Main.

No. 8 manifold connection ready for a 3-inch service pipe, though it would be preferable to stagger the service cocks or to place them spiraliy.

Table XI. gives the details of galvanized pipe used for service connections and Table XII. the same for lead pipe.

TABLE XI.—GALVANIZED IRON SERVICE PIPE.

Diameter Inches.			Nominal Weight per Foot. Lbs.	No. of Threasd per Inch of Screw.	Contents in Gallons per Foot
Nominal Internal.	Actual External.	Actual Internal.			
½	0.84	0.623	0.837	14	0.0102
¾	1.05	0.824	1.115	14	0.0230
1	1.315	1.048	1.668	11½	0.0480
1¼	1.66	1.38	2.244	11½	0.0638
1½	1.9	1.611	2.678	11½	0.0918
2	2.375	2.067	3.609	11½	0.1632
2½	2.875	2.468	5.739	8	0.2550
3	3.5	3.067	7.536	8	0.3673

TABLE XII.—LEAD AND TIN-LINED LEAD SERVICE PIPES.
WEIGHT PER FOOT.

INSIDE DIAM.	A A A.		A A.		A.		B.		C.		D.		E.	
	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.
½	3	0	2	0	1	12	1	4	1	0	0	12	0	9
⅝	3	8	2	12	2	8	2	0	1	8	1	0	0	12
¾	4	12	3	8	3	0	2	4	1	12	1	4	1	0
1	6	0	4	12	4	0	3	4	2	8	2	0	1	8
1¼	6	12	5	12	4	12	3	12	3	0	2	8	2	0
1½	8	8	7	8	6	8	5	0	4	4	3	8	3	0
1¾	10	0	8	8	7	0	6	0	5	0	4	0		
2	11	12	9	0	8	3	7	0	6	0	4	12		

A few cities use cast-iron service connections. For this purpose a special pipe of small diameter is cast. The outside diameter is the same as the outside diameter of wrought-iron pipe, but the inside diameters do not correspond. It is made in this way in order that the same fittings may be used, if desired, as are used for wrought-iron pipe. The pipe is named the same as the size of the wrought-iron pipe that the fittings are made for, thus what is known as 1½-inch cast-iron pipe takes the same fittings as 1½-inch wrought-iron pipe, has the same external diameter as the latter, but not the same internal diameter. The pipe is made in lengths of 7 feet for the 1½-inch and 2-inch sizes, and in 12-foot lengths for the larger sizes, with either screwed ends for use with wrought-iron pipe fittings, or with hub and spigot ends for the ordinary lead joints. Table XIII. gives the details of the various sizes of this pipe.

TABLE XIII.—SMALL SIZES OF CAST-IRON PIPE.

TRADE SIZE.	Nominal Inside Diameter.	Actual Outside Diameter.	Nominal Thickness.	Weight Per Foot.	Length in Feet.
1½	1¼	1.90	5-16	5	7
1½	1⅜	1.90	¼	4	7
2	1¾	2.375	5-16	7½	7
2	1⅞	2.375	¼	6	7
2½	2 1-8	2.875	3-8	10½	12
2½	2¼	2.875	5-16	8	12
3	2¾	3.50	3-8	12½	12
3	2⅞	3.50	5-16	10	12
3½	3¼	4.00	3-8	14½	12
3½	3⅜	4.00	5-16	12½	12
4	3 5-8	4.50	7-16	21	12
4	3¾	4.50	⅜	18	12

The light-weight pipe is not coated unless it is so ordered. The heavy-weight pipe is coated inside and outside with coal-tar varnish. Light-weight pipe is tested to 150 pounds per square inch, and heavy pipe to 300 pounds per square inch. The advantage of cast-iron pipe over wrought-iron for service connections lies in its great durability. The use of this pipe is not very extensive as yet, as it has but recently been placed on the market.

Tapping Machines. The mains may be tapped either dry or under pressure. If tapped dry or with the pressure shut off the tools required are simple and cheap, being a ratchet drill, with

FIG. 81. Apparatus For Dry Tapping.

crow, a tap or threading tool and a monkey wrench. Fig. 81 shows a dry-pipe tapping machine.

Of recent years, however, tapping under pressure has come into vogue very generally, and a water works is hardly considered complete now that has not facilities for such work. By this method the water does not have to be shut off and none of the consumers are inconvenienced. There are a number of machines on the market for this purpose, one of which is shown in Fig. 82. They are attached to the mains by means of a chain, which can be tightened up, a thick gasket of rubber being interposed between the machine and the main to prevent leakage. A casing on the machine contains a drill and threading tool combined, Fig. 82, *A*.

After the machine has been properly attached to the main the drill is moved into position and the hole bored and threaded. The drill and tap are then backed out and the gate, *C*, closed. The top is then removed, the drill and tap taken out of the spindle and the plug, *B*, inserted in the spindle. The corporation-cock after

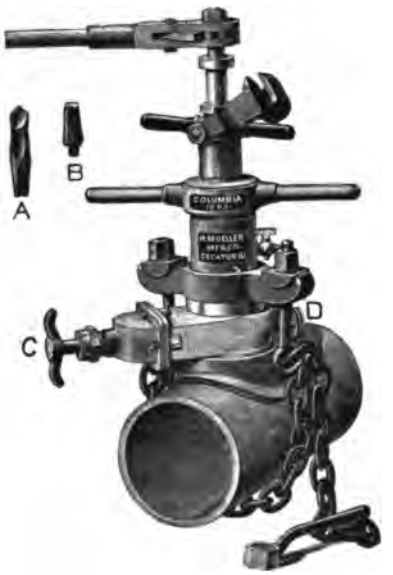


FIG. 82. Machine For Tapping Under Pressure.

having been closed is screwed on to the plug, *B*, and the top of the machine replaced, the by-pass, *D*, and then the gate, *C*, opened and the cock screwed into the main. The machine is then removed and the corporation-cock screwed up tight with a wrench.

While the other machines on the market all differ in details, still they all accomplish the same ends. In addition to the advantages named above, the trench is kept dry and the workmen are not inconvenienced.

Many towns and companies set aside one or more certain days in the week for tapping, and will not do it at other times. No one but the person regularly employed to make the taps should be allowed to make any connection whatever with the mains. Any work done upon the mains should only be done by the regular employees, for that purpose, of the department or company. The plumber employed by the consumer digs the ditch and has everything in readiness for the tapper, whose work ends with the putting-in of the corporation-cock. A charge is usually made for the cock and tapping, and it is frequently the custom for the company or department to furnish the service-cock and box and the cock for the cellar at established prices, in order to insure uniformity.

A complete record, giving all details, should be kept of every tap and connection made.

A FEW HINTS TO STUDENTS OF IRRIGATION ENGINEERING.

By A. M. RYON, E. M.

If ever an accounting of good works is made, the engineering profession will not be found in the back row; but if by chance the designers of iron and steel work for high buildings should be found on the doubtful bench, assuredly they will not have the company of irrigation engineers to console them. It is difficult to imagine, from a professional standpoint, a more satisfactory work than the conversion of an arid desert into fertile fields with the accompanying population and improvements.

In the United States much work of this nature, involving no great amount of engineering skill, has already been done in the way of running small ditches from the streams and distributing the water where desired. Many large canals requiring a considerable degree of engineering skill and experience for their proper construction have also been built, so that the land upon which water may be profitably placed by individuals or small companies of limited means is now becoming scarce. The engineering work of the future will, therefore, consist of enterprises involving the design and construction of canals of large capacity with their accompanying dams, gates and other fixtures.

Graduates from our engineering colleges receive a preliminary training, which, if properly continued after graduation, particularly fits them to occupy prominent and permanent positions in this great work of reclamation.

The irrigation engineer should not be content to merely design and construct these works, leaving the care and management of them after completion to business men or farmers, with a few ditch tenders to assist. If the engineer would inform himself of the irrigation laws and also of the business side of the undertaking he might become a more prominent figure in the councils of the Company and would have a better opportunity to impress upon the owners the necessity of good management of the property when completed, as well as what constitutes good management.

The average Westerner is obliged to rely upon his own inventive powers to a great extent, having no precedents to guide him in many matters; this naturally makes him self reliant, and possibly

over-confident of his own abilities. It is this feeling of confidence which often impels men to undertake work for which they are not fitted and which frequently results in great and unnecessary expense to themselves. Unfortunately, such men are often blind to the loss, or they consider that another would probably have made similar blunders under the same conditions. The value of the services of a trained engineer is not appreciated in such communities, as he is apt to be regarded as a theoretical person who may be made use of to locate corners or run levels, but of very uncertain value when it comes to "practical" matters. We cannot blame the Westerner for this attitude, as he is more familiar with the surveyor than with the engineer, and the distinction between the two is not always clear to him. This state of affairs naturally prejudices the interest of the engineer and makes it necessary for him to demonstrate his value.

However, it is comforting to know that every day brings increased recognition in the West of the value of the services of the irrigation engineer, not only as a designer and constructor, but as general manager for large irrigation works.

At first sight projects for the reclamation of arid land present rather an alluring appearance to the speculative capitalist; a closer inspection, however, is apt to have a dampening effect. A considerable amount of labor and close figuring is apt to result in fair profits to the investor, but excessive profits are difficult to realize. The reason for this may be seen from what follows.

The proper and most satisfactory organization is that in which the owners of the land are also owners of the canal and water right. This will be readily seen when it is borne in mind that the land is practically valueless without water in quantities sufficient for irrigation. In some communities large districts, with all their improvements, are bonded for the purpose of raising funds to supply the necessary water. Often the entire labor of constructing canals is done by farmers owning land to be supplied, thereby receiving water privileges in return. These methods necessitate the outlay of a comparatively small amount of ready money by those benefited and are entirely practicable.

Where the canal is built by capitalists who have purchased arid lands in large quantities, hoping to sell to settlers upon the completion of the work, thus necessitating a large outlay of money which can bring no return until land is disposed of to purchasers,

failure will be the probable result. The reason being that farmers, as a rule, have but little ready money, and those who have money prefer not to experiment by moving into new and untried fields. As a result the interest charges on sums paid for land and canal, which bring little or no return for long periods, eventually reach such a figure as to preclude the possibility of the investor ever realizing a fair retnrn on his investment.

I believe that it is not outside the province of the irrigation engineer to study the conditions favorable and unfavorable to the success of the project from a financial as well as from a strictly engineering standpoint and to use this information to warn his employer of pitfalls. A good lawyer will not only use his influence to keep his clients from calamitous lawsuits, but he will also place his knowledge of men and affairs at the disposal of those who employ him. I see no reason why an engineer should not occupy much the same position. A fee, no matter how large, will not repay a conscientious engineer for encouraging a project, even by his silence, which is bound to result in a loss to those who employ him. Even if the warning be disregarded, there can be but little pleasure in looking back at a work done which failed in the object for which it was commenced.

In India, where irrigation works are constructed by the government, and in some portions of Spain and Italy we find some very substantial masonry construction, such as the engineer delights in. In the United States, where interest rates are high and first cost a prime consideration, we are obliged to use cheap material, which brings the interest bill down, but also brings the maintenance bill up. As a rule financial considerations necessitate a cheap construction of new irrigation plants, although more permanent construction may sometimes gradually replace the old work with advantage.

The designing of the various details of a canal, as well as the surveys, is essentially an engineering problem, although it may be difficult to convince some ranchmen that such is a fact. We have first the reconnoissance, then the preliminary, and finally the location surveys, followed by the construction of the canal. As a rule the larger the canal the more carefully this work should be attended to. In the case of a ditch carrying from 1 cu. ft. to, say, 10 cu. ft. per second, these surveys may often be advantageously combined in one operation. A very common rule in the West for

small ditches is to lay them out with a grade of ¼ inch to the rod, but it is quite essential that the slope be in the right direction. I have on more than one occasion seen "monuments" as results of the efforts of cheap (?) surveyors. The main trouble with these "monuments" seems to be that they will only carry water *towards* the source of supply. It is needless to say that this sort of surveying has resulted in several parties "going broke," as the mistake is not apt to be noticed until after the ditch is completed.

For the survey of a small ditch, in the absence of a wye level, a straight edge one rod long, with a small spirit level attached, is often employed; a small block attached at the end of the rod serves to indicate the grade. Cuts and fills are, as a rule, avoided. If it is desired to cross a low place a flume should be used, as ditches placed in artificial banks are apt to prove troublesome by reason of washouts, caused by leakage and by cattle.

The topography of the ground and the character of the soil through which a canal is to pass is a matter requiring the careful attention of the designer. In general a steep side hill requires a deep ditch, while a shallow construction may be advantageously used on flat ground. Tunnels should have a steep grade on account of the roughness of their sides, if unlined, and in order to reduce their cross section to a minimum; very steep side hills will require a flume, but, as a flume involves a heavy bill for maintenance, masonary may sometimes be substituted with advantage.

In the arid West we frequently find a white soil, composed mostly of silica and carbonate of lime, which may be reduced to a fine powder by rubbing between the fingers. Although this material is so hard that blasting may sometimes be used with advantage in passing through it, contact with water reduces it to a condition approximating quicksand. Where much of this material is found on a steep side hill the engineer would do well to change the line of the canal, if possible, so as to avoid the difficulty, otherwise there will be trouble ahead.

Gravel is a material which would impress many as being particularly undesirable for a canal bank, on the ground that a material suitable for filtering purposes cannot be desirable where a water-tight construction is needed. This sounds reasonable, yet we have numerous examples of side-hill work in gravel which are satisfactory in every way. It is true that a gravel bank will allow large quantities of water through at first, but it will not wash out, and

where the water carries silt, as is generally the case in irrigation canals, the openings are gradually filled on the water side, and the bank becomes tight. We will then have a bank of high specific gravity, not liable to be perforated by animals, and one which requires but little expense for maintenance.

These advantages will also hold true for dams. As a rule an irrigration canal is not taxed to its utmost capacity at first, so that the leakage at that period is not so objectionable as it would be later.

Damage is frequently done to canal banks during the winter by the snow water running down small gullies into the canal, and, being prevented from flowing along the canal by the snow and ice, is apt to make breaks by running over the top of the bank. Waste gates should be placed at all such places liable to damage.

During the irrigating season every possible precaution should be taken against a break occurring in the canal, for, aside from the damage to the canal itself and the land immediately underneath, the loss by reason of crops "burning up" may be very heavy. Constant inspection is the price of security in this direction.

It sometimes becomes desirable to carry water down such steep grades that the high velocity generated will cause a scour. This may be obviated by the use of drops, as described in works on irrigation, or in some cases the difficulty will gradually disappear without any special precautions on the part of the designer. As, for example, where the soil contains much gravel or where the gravel subsoil comes near the surface. In such cases the ditch will scour until a certain depth is reached, then, owing to the gravel bottom, it will continue to widen but not to deepen. The resistance due to friction being increased, while the head and volume of water flowing remain the same, the velocity will be decreased and the lining of the ditch will become of such a character that no further damage will result. The ultimate dimensions may be approximately calculated for any given case. If there is liable to be damage by reason of the deposition of sand at a point lower down the ditch or canal, precaution should be taken to use a sand gate before the mischief is done.

The head-gate works are worthy of the most careful attention of the designer and the superintendent, as an accident at this point may result in very serious loss. For this reason it is highly desirable to have two independent gates, either of which may be used

in case of a failure on the part of the other; this may usually be accomplished by carrying the canal for a short distance in a direction approximately parallel to the direction of the stream from which the water is taken. The down-stream gate in the canal may be used in case repairs to the upper gate make it necessary to shut off the water at that point. Where the banks of a river are liable to be washed by freshets the design of the head works is often perplexing and their construction expensive.

Where timber is used, as in ordinary practice, quantities of loose rock and coarse gravel are found desirable to prevent the head-gate works from floating off. This tendency to float when the gates are closed may be corrected to a great extent by placing the gates as near the down-stream side of the box as practicable, due care being taken to prevent the flowing water in the canal from scouring underneath the box. The gates themselves are usually opened by inserting bars in openings in the stems and prying with a rock or some block of wood serving as a temporary fulcrum; this method is rather crude and suggestive of the ranch, but has the advantage of cheapness and answers fairly well so long as the stems last, very large canals, however, will warrant a more expensive construction which can be relied upon not to break at just the wrong time.

In the construction of flumes and boxes, no matter how small, avoid the temptation to use any planking less than two inches thick. Thin plank may be relied on to warp and make more trouble than the saving in first cost amounts to. In designing flumes see that the side boards are nailed to the bottom boards, rather than the bottom boards nailed to the side; this arrangement, although an apparently trifling detail, will save much trouble in maintaining a tight joint at that place. As many examples of excellent fluming are illustrated in irrigation and mining publications, further comment need not be made here.

The measurement of water in the main canal may be made by means of a current meter in some straight flume not likely to silt up. Several measurements with varying volumes of water flowing should be taken and the height of the water on a permanent gage noted for each measurement. Knowing the volume of flow for each of the different heights, a curve can be drawn which will give the flow for any intermediate heights. In this way the observer can determine the flow at any time by merely noting the height

of water on the gage and referring to a table compiled from data supplied by the curve. As flumes have a tendency to settle, these measurements should be checked occasionally. If a permanent record showing the flow at any hour of any day is desired, a "water register" may be used. This register consists of clockwork causing a dial on a cylinder to revolve, once a day or once a week, as the case may be, while a float in the water actuates a pen which marks on the dial the height of the water.

Small sliding gates with a vertical motion are used to regulate the amount of water turned into laterals for the use of consumers. These gates are also sometimes used to measure, approximately, the water flowing through them.

In many parts of the West the old fashioned loose method by means of the "miners' inch" or some "statutory inch" based on the same principle is still in use. The popularity of this method of measurement indicates that it is not without advantages; but the superiority of the weir for such purposes in any but very new countries is evident to engineers. Each succeeding year finds fewer adherents to rule of thumb methods and eventually the miners' inch will become a thing of the past in this country.

GOLDEN, COLO., FEBRUARY 14, 1897.

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In my article on "The Calculation of Copper Matte Blast-Furnace Charges," which appeared in Vol. XVIII., No. 1, of the QUARTERLY, there is an error which I would like to have corrected. On page 2 I state "Manganese replaces iron and renders the slag extremely fusible; but Iles considers Manganese as detrimental on account of its tendency to carry silver into the Slag. Church, however, does not consider Manganese as detrimental and claims to have made slags containing over 43 per cent. MnO which were remarkably low in silver (0.5 oz. per ton)."

This should read as follows:

Manganese replaces iron and renders the slag extremely fusible; but some Metallurgists have considered Manganese as detrimental

on account of its supposed tendency to carry silver into the slag. Ilis* has shown that this is an error and that Manganese is quite as good a flux as iron. Church† claims to have made slags containing over 43 per cent. MnO which were remarkably low in silver (0.5 oz. per ton)."

As I have unintentially misquoted Dr. Iles, I hope you will make this correction in the next number of the QUARTERLY.

Yours truly,

H. VAN F. FURMAN.

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* SCHOOL OF MINES QUARTERLY, Vol. V., p. 217.

† Trans. Am. Inst., M. E. Vol. XV., p. 612. SCHOOL OF MINES QUARTERLY, Vol. V., p. 322.

ABSTRACTS.

ANALYTICAL CHEMISTRY.

By ELWYN WALLER, PH.D.

Hydrochloric acid gas in metal separations. Moyer (J. Am. Chem. Soc. XVIII. 1029).

The oxides of the different metals were placed in a boat, inside a tube, and *dry* HCl gas passed over them, heat being applied as might be required.

The following results were obtained:

Sb_2O_3 complete volatization at 150 to 190° C.

PbO complete volatilizaton at 225° C.

Separating Pb from Sb. HCl gas passed cold until Pb was converted to $PbCl_2$, then a gentle heat was applied. Sb was completely volatilized off in about 7 hoars.

Bi_2O_3 volatilization occurred at 130° C.

Separating Bi from Pb. The gas was allowed to act in the cold for an hour, then heat was applied. If the temperature was brought to over 180° C. some $PbCl_2$ volatilized. A complete separation is attainable, but the termination of the different stages of the reaction is not marked definitely by phenomena which can be readily noted.

CuO no action at 175° C. Moistening with HCl solution and then heating for 2 hours gave complete conversion to $CuCl_2$. Without previous moistening with HCl, the conversion was complete in the course of 4 hours.

Separating Sb from Cu. Complete separation in 8 hours.

Separating Bi from Cu. Separation in 7 hours. A sharp raising of the temperature toward the end seemed advantageous.

As was volatilized in the cold from $Na_4As_2O_7$, leaving NaCl.

Separating As from Cu. Readily effected with gentle heat.

Separating As from Ag. Reaction vigorous. Careful heating to 150° C. for 1 to 2 hours gave perfect separation.

Separating As from Cd. Separation perfect at 150° C.

Fe_2O_3. Partial volatilization.

As from Fe. Separation imperfect.

As from Zn. Unsatisfactory results. $ZnCl_2$ did not volatilize.

As from Co and Ni. Satisfactory volatilization of As.

From Niccolite the As was easily and completely separated. Hibbs. (ib. 1044), has applied the use of dry HCl gas in determining the atomic masses of N and of As.

Field and Smith (ib. 1051), have also applied it to the separation of Vd and As. Those elements were obtained as mixed sulphides, dried, and then subjected to the action of dry HCl. Most of the As was volatilized at ordinary temperatures. The separation was made complete by finally heating to 150° C.

Kelley and Smith (ib. 1096) have found also that As_2S_3, and Sb_2S_3 and SnS_2 can be volatilized in a current of HBr gas under the same conditions. SnS subjected to the action of dry HCl gas afforded $SnCl_2$

which was not volatilized. Attempts to separate stannic from stannous compounds by this means, were unsatisfactory in result.

Standardizing Permanganate Riegler (Fres. Zts. Anal. Chem. XXXV. 522.) The solution recommended contains 9.9654 gms. pure $H_2C_2O_4$ $2H_2O$ and 50 cc. conc. H_2SO_4 per litre. This solution will keep well. 1 cc.= 0.005 gm. $K_2Mn_2O_8$.

Calcium carbide as a reducing agent in the laboratory. Warren. (Chem. News LXXV. 2.) The results of a few experiments are briefly noted. Heated with litharge—alloys of Ca and Pb were obtained. SnO_2 CuO or Fe_2O_8 treated in the same manner afforded similar results of no practical value. Results with oxides of Mn, Ni, Co, Cr, Mo and W, seemed more promising. Experiments with other oxides are in progress.

Alkalimetric Indicators. Crismer. (Bull. Ass'n. Belge X. 22.) Resazurine is the substance described. It is made by dissolving 10 gms. resorcin in 500 cc. of ether, cooling to 5°C. and adding 8 gms. fuming HNO_8 diluted with ether. After standing several days, crystals will have separated, which can be collected. For use dissolve 0.20 gm. in 40 cc. $N/_{10}NH_4OH$ and dilute with water to one litre.

It gives intense blue with alkalies and their carbonates—(also with borax), and red with acids. It is more sensitive than turmeric.

Verbiese, (J. fabr. sucre. XXXVII. 20.) Notes that solutions of some indicators in alcohol (phenolphthalein) often become useless from formation of acetic acid.

Calcium oxalate precipitation. Lemvine. (Bull. Ass'n. Belge. X. 124.) To avoid the difficulties of filtering this precipitate off clear, which sometimes is a troublesome matter, it is recommended to add $H_2C_2O_4$ to the solution and then HCl until the solution clears. Then boil and after a time neutralize with a slight excess of ammonia. Boil ten minutes when the precipitate will easily separate and give no trouble.

Solubility of Barium Sulphate. Küster. (Zts. Anorg. Chem. XII. 261.) The results of Fresenius and Hinz (vid. QUARTERLY XVIII. 53) indicate the solubility to be 1 in 110,000 of water. By testing the electrical resistance, the solubility is determined to be 1 in 425,000. This result agrees with those of Kohlrausch, Rose, and Holleman.

Separating Aluminum from Iron. Gooch and Havens. (Am. J. Sci. [4] II.) It has been noted that Al_6Cl_8,H_2O is but little soluble in conc HCl, while the ferric compound is quite soluble. Addition of a sufficient quantity of ether renders the Al compound sufficiently insoluble to afford a means for quantitative separation. The mixed chlorides are dissolved in as little water as possible, strong conc HCl is added to make the volume up to 15 to 25 cc., and dry HCl gas passed into saturation, the solution being meantime kept cool by immersing the flask in a current of cold water. Then an equal volume of ether is added, and the mixture is again treated with gaseous HCl. The crystalline $AlCl_3$ is then filtered off through a Gooch crucible, and washed with a mixture of conc HCl and ether (saturated with HCl gas). It may then be dissolved in water and Al_2O_3 determined as usual, or the chloride may be covered in the crucible with a little puré HgO after drying, and then cautiously ignited to to Al_2O_3 finishing with the blast.

Commercial Aluminum. Gouthière. (Ann. Chim. Analyt. I. 265.) *Cu, Pb, Fe Ni.* Treat 5 to 10 gms. of turnings in an Erlenmeyer flask with successive additions of NaOH (1:3) keeping the heat up all the time.

Decant through a small filter, and wash with boiling water, dissolve the residue in HNO_3—evaparate off the excess of acid, etc., add 2cc. HNO_3 and electrolyze at 60 to 65° C.—obtaining Cu on one pole, and PbO_2 on the other. Precipitate Fe from the solution by NH_4OH, and if Ni is present redissolve and reprecipitate once or twice more, finally electrolyze the filtrate for Ni.

For *Sn and Sb* dissolve in HCl, nearly neutralize with $(NH_4)_2CO_3$, and precipitate by H_2S. Digest the precipitate for some time warm with $(NH_4)_2S$. Precipitate by dilute HCl, filter ignite to SnO_2 and weigh. Sb is rarely present. If the color of the sulphides indicates it, some one of the usual methods of separation must be applied. *Zn* may be separated in the filtrate from SnS_2 etc., by adding $NaC_2H_3O_2$ and passing H_2S.

As. Dissolve the sulphides from 5 gms. of the material in a little HNO_3 add H_2SO_4 evaporate to fumes, evolve AsH_3 in a Marsh apparatus passing the gas into $AgNO_3$. Weigh the Ag precipitated.

Si. Dissolve 5 gms. in HCl with some HNO_3, evaporate to dryness, until all acid is expelled, heat to 111°–120° C., digest with dilute HCl, filter, wash, dry and calcine in a muffle.

Carbon. Boussingault's method is preferred. Treatment with $HgCl_2$ digestion in dilute HCl, and heating in a current of H. One may use Ullgren's method—Solution in $CuCl_2$, $2NH_4Cl$, and wet combustion with H_2SO_4 and CrO_3.

S. Rollet's method. Heating 2 gms. in a current of two vols. H and one vol. CO_2, and passing the H_2S obtained through $AgNO_3$.

Analysis of Refined Zinc. Mylius & Fromm. (Zts. Amorg. Chem. IX. 148.) For Pb, Cd. and other metals forming sulphides insoluble in $(NH_4)_2S$. Cover 100 gms. of the shavings with 200 cc. of water and add gradually HNO_3 sufficient to dissolve. Supersaturate with ammonia. Dilute to 2 litres, and add little by little very dilute $(NH_4)_2S$ until the precipitate which forms on the addition has the clear white color of ZnS. Warm to 80°C and allow to settle. Filter and test the filtrate with $(NH_4)_2S$ which should give a perfectly white precipitate of ZnS without a trace of the yellow of CdS on warming. Dissolve the precipitate in HCl, add H_2SO_4 and evaporate to fumes, dilute, add alcohol, filter out $PbSO_4$. Saturate the filtrate with H_2S, then nearly neutralize with NH_4OH, to separate Cd. Filter off and precipitate Fe by NH_4OH. The Cd and Fe precipitates need to be redissolved and reprecipitated to free them from Zn. Ag, Hg, Cu and Bi can also be determined by this plan of procedure.

Arsenic by Reinsch's test. Howe and Mertens. (J. Am. Chem. Soc. XVIII. 953.) Deposit on metallic Cu by boiling, and subsequent volatilization of As_2O_3, by heating in a tube open at both ends. The delicacy of the test is fully that claimed by Reinsch. (1 part in over 300,000.) The deposition of Sb on the Cu occurs with more difficulty than As, the coating has a distinctly different tint, and the sublimate in the tube is amorphous—altogether different from the crystalline sublimate of As_2O_3.

Gold in Sea Water. Sonstadt. (Proc. Lond. Chem. Soc. No. 171 p. 236.) About 20 gms. pure Hg was agitated in a flask with about half a gallon of the water for a long time, with heating on a water bath at intervals. The Hg was separated, washed, dried with bibulous paper and volatilized in a porcelain crucible having an uninjured internal sur-

face. A black residue remained, some of which dissolved off in HCl. The remainder was only soluble in aqua regia and on cupellation yielded a minute button of Au. Sea water collected near the shore and shipped in casks appeared to contain less Au than that collected further out and treated directly. The contact with wood, or the separation of salt, may one or both have caused this. Incidentally it was noted that the Hg extracts Ag also from the sea water.

Volumetric Estimation of Lead. Longi and Bonavia (Gaztta. XXVI., I. 327). The various methods proposed have been carefully examined. Na_2S solution affords an uncertain end-reaction.

Hempel's method—precipitating with oxalic acid and determining the oxalic acid in the precipitate or in the filtrate by permanganate, is only serviceable when certain precautions are taken; an excess of oxalic acid must be used in concentrated solutions, HNO_3 must be absent, and alcohol must be used to obtain the insolubility of PbC_2O_4.

The dichromate titration, using $AgNO_3$ for the end-reaction, is unsatisfactory, the suspended $PbCrO_4$, reacting with $AgNO_3$.

Precipitating with K_2CrO_4 and determining the excess by ferrous salt gives poor results. The use of $Na_2S_2O_3$ to determine the excess is still less satisfactory. Addition of KI to the filtrate and acidifying with HCl, and then titrating the I set free by use of $Na_2S_2O_3$ gave good results.

Haswell's permanganate method was found unsuitable. Precipitation with standard ferrocyanide, filtering, and determining ferrocyanide either in filtrate or precipitate by means of permanganate is good, if atmospheric oxidation of the ferrocyanide is prevented.

Electrolytic Determination of Lead. Neumann. (Chem. Ztg., XX. 381.) The presence of As, Se or Mn, unless small in amount, interferes with accurate determination of Pb (as PbO_2 from HNO_3 solution). As or Se above 0.5 per cent. is detrimental, or Mn above 3 per cent.

Separation of Lead and Bismuth. Benkert and Smith. (J. Am. Chem. Soc. XVIII. 1055.) To a solution containing known amounts of the metals as nitrates, Na_2CO_3 was added nearly to neutralization, then a solution of $NaCHO_2$ and a few drops of $HCHO_2$. Then on boiling a precipitate consisting chiefly of basic bismuth formate was separated. On redissolving in HNO_3 and repeating the operation, a complete separation was effected.

Bismuth Sulphide. Stone. (J. Am. Chem. Soc. XVII. 1091.) Prof. Stillman has noted that if NaOH is added to a solution of Bi, and the mixture is then heated with $(NH_4)_2S$, a considerable amount of Bi is held in solution. The author finds this to be correct, but has also found that Bi_2S_3 after precipitation from an acid solution is practically insoluble in $(NH_4)_2S$ solution.

Determination of Bismuth. Muthmann and Mauron. (Zts. Anorg. Chem. XIII. 207.) Precipitation with hypophosphorus acid, washing with water, then with alcohol, drying and weighing the metallic Bi, gave correct results.

Cadmium Estimation. Browning and Jones. (Am. J. Sci. II. [4] Oct., 1896.) Precipitation as $CdCO_3$ and igniting after filtering through paper, etc., gives low results, if the product is assumed to be CdO. It has been surmised that this was due to a partial reduction of the CdO. Filtration through an asbestos filter previously ignited has been found to give accurate results.

Lead and Copper in Waters. Egeling. (Med. Tydschr. Pharm. 1896. 113.) Saturates with H_2S, then shakes with about 0.5 gm. of talc, which has been previously boiled in HNO_3. The talc helps to collect the precipitate which may then be filtered off, dissolved etc. Antony and Benelli (Gaceta XXVI., I. 218.) Add $HgCl_2$ and then pass H_2S. The HgS carries with it the other sulphides after adding NH_4Cl. On heating the dried precipitate in a current of H_2S, the HgS may be volatilized off, leaving the less volatile PbS etc., or the precipitate may be treated with H_2SO_4, and weighed as $PbSO_4$ after ignition.

Colorimetric for Copper. Heath. (J. Am. Chem. Soc. XIX. 24.) In the "blue" test (comparison of NH_4OH solutions) permanent standards can be prepared by using a sulphate solution, and a sufficient excess of NH_4OH, and keeping the standard tubes well stoppered. Prepare standards by dissolving 0.3 gm. pure Cu in 5 cc. HNO_3 (Gr. 1.4) and 5 cc. conc. H_2SO_4 evaporate to strong SO_3 fumes, cool dilute with 25 cc. of water, and then add strong NH_4OH sufficient to produce a clear solution. Use diluted ammonia to (1 vol. to 6 of H_2O) for diluting the solution until 1 cc. contains 0.0025 gm. Cu. Then make up a set of standards, containing from 0.0025 up to 0.0325 gm. (0.10 to 1.30 per cent. when 2.5 gms. of material is taken.) Dilute each up to 200 cc. with the weak NH_4OH, and stopper up tightly. Of course care in selecting stoppered tubes of colorless glass and uniform calibre is necessary.

To make the test, pulverize the ore, etc., finely, weigh out 2.5 gms., warm with 15 cc. HNO_3, stir, add 5 cc. conc. H_2SO_4, boil down to fumes, cool, take up with 12 cc. of water, add excess of NH_4OH, filter and wash with weak NH_4OH, stirring up the precipitate in the funnel occasionally with a rod. For a working (approximate) test making the filtrate and washings to 200 cc. mixing and comparing will suffice. For a closer determination, resolution of the $Fe_2(OH)_6$, etc., in H_2SO_4 and reprecipitation with NH_4OH is necessary. In this case, the first solution should be only about 70 cc. Another method, perhaps more accurate, consists in precipitating the Cu from the acid solution by means of a strip of Al, dissolving the washed Cu in HNO_3 and H_2SO_4 as in standardizing and continuing the operation as described under that head, finally making up to 200 cc. for comparing.

Separation of Thorium. Denius. (J. Am. Chem. Soc. XVIII. 947.) Adding a slight excess of potassium trinitride to a neutral solution of the chlorides and boiling for one minute was found to separate thorium quantitatively for La, Di, Ce, etc., HN_3 was volatilized during the boiling. The reaction with $Th(NO_3)_4$ was found to be:

$$Th(NO_3)_4 + 4KN_3 + 4H_2O = Th(OH)_4 + 4KNO_3 + 4HN_3.$$

Separating Manganese from Tungstic Acid. Taggart and Smith. (Jam. Chem. Soc. XVIII. 1053). Digestion with $(NH_4)_2S$ and NH_4Cl, also digestion with K_2CO_3, were tried. Neither gave satisfactory results. In the first case WO_3 remained with the MnS; in the second some MnO went with the WO_3.

Phosphates in Coal. Campredon. (Chem. News, LXXV. 8). Fusing 0.6 gm. of the coal with 3 gms. of a mixture of Na_2CO_3 with K_2CO_3 for 10 to 15 minutes, extracting with acidulated water (HCl) and determining by the molybdate method, is recommended as the most accurate.

Sulphur in Iron or Steel. Boucher. (Chem. News, LXXIV. 76.) The

Fe is dissolved off by $Cu(NH_4)_2Cl_4$. Instead of treating the residue with aqua regia, as usual, it is oxidized with Br water and HCl, which affords results a little higher than by the aqua regia method.

Sulphur in Irons. Phillips. (J. Am. Chem. Soc. XVIII. 1079.) An account is given of attempts to oxidize all the constituents in a cast-iron by fusion with alkaline oxidizing agents, with especial view to determination of the S. White iron, pulverized and sifted through bolting cloth showed some unoxidized carbon after fusion with $NaNO_3$ and Na_2CO_3. When some Na_2O_2 was added to the flux no C was unoxidized. Ferro-manganese crushed and sifted was sufficiently oxidized by fusing with $NaNO_3$ and Na_2CO_3. When Na_2O_2 was used, green Na_2MnO_4 was formed, which was not the case without it. Gray iron, as finely subdivided as possible, left no unconsumed graphitic carbon on fusion with $NaNO_3$ and Na_2CO_3.

The water solutions from these fusions, after evaporating with Br water, acidulating, etc., gave results for S a little higher than by the ordinary method of oxidation by boiling with HNO_3.

Carbon Dioxide in the Atmosphere. Letts and Blake. (Proc. Lond. Chem. Soc. No. 169, 192.) The alkalinity derived from glass vessels is a decided source of error in the Pettenkofer method. Using receivers and also bottles for the standard solutions which had been coated inside with paraffine, gave accurate results.

Modification of the Gunning method for Nitrates. Field. (J. Am. Chem. Soc. XVIII. 1102.) After weighing out the material, and placing in a digestion flask 30 cc. conc. H_2SO_4 and 1 gm. salicylic acid are added, and it is gently heated for some little time. Then while warm 6 to 7 gms. of K_2S are added in small portions at a time, the flask being well shaken after each addition. Then the mixture may be brought to a boil, and kept at that point until completed. An hour is usually sufficient. The rest of the operation is conducted in the usual manner.

The necessity for close attention to the operation to prevent losses by frothing, etc., in the ordinary Gunning method is avoided in this modification.

Nitrous acid in presence of sulphites. Pechard. (C. Rend. CXXXIII. 590.) The water or washings from the lixiviation of a soil is brought to a boil in a flask, which is then stoppered and shaken from time to time until completely cold. Filter through bone black. Then place a drop on a porcelain plate, add a drop of *pure* HCl (Gr 1.21), spread with platinum wire to the size of a silver dime (half franc), and drop in to the centre a fragment of brucine the size of a pin head. If in the course of 5 minutes a coloration varying from vermillion to light yellow is observed, nitrites are present. The delicacy of the reaction is 1 part in 329,000.

Cyanide process. Laboratory control. Furman. (Am. Inst. Min. Eng. Colorado meeting, Sept., 1896.) KCy solution of 0.5 to 0.6 per cent. should be used. The strength should be determined from time to time by Test 6.

1. *Acidity* of the ore. *Soluble.* Agitate 10 gms. of pulp with 50 cc. of water, filter and wash if necessary until the washings are neutral. Titrate with N/10 NaOH. *Latent.* Transfer the washed ore to an evaporating dish, covered with water, add a known amount of $N/_{10}$ NaOH (excess), stir and titrate excess. *Total* acidity is the sum of that soluble and latent.

2. *Consumption of Cyanide.* Agitate 20 gms. of the ore with 40 cc. of the KCy solution, filter off 20 cc. and determine KCy remaining.

3. *Percentage of Extraction.* Two tests *a Agitation* and *b Percolation.* *a.* Add a sufficient CaO as neutralizer (determined by test 1) after weighing out four lots of one assay ton each. Then add to each respectively, 60 cc. of solutions containing 0.1, 0.3, 0.5, and 0.75 per cent. KCy. Allow to stand 48 hours with occasional shaking. Filter each, wash with water up to the original bulk. Test each for loss of KCy. Dry tailings and assay. *b.* Invert a bottle with bottom cut off, the cork being provided with a tube and stop cock. Use 1 lb. of ore placed on a false bottom covered with one or two thicknesses of filter paper. Pour on a definite amount of KCy solution of known strength, let macerate 12 hours, then slowly percolate off (30 to 40 hours). Wash up to original bulk, and test solution and tailings as before.

4. *Cause of Cyanide Consumption.* For every part of KCy destroyed, a corresponding amount of metal enters into solution. Fe, Al and Mg oxides are the principal ones influencing the process. Sulphides may afford KCyS. Agitate 100 gms. of ore with 200 cc. of KCy solution, filter off 20 cc. evaporate first alone, afterward again with strong H_2SO_4, and determine the oxide present. HCl is inefficient in destroying the cyanides which may be formed.

5. *Cause of Non-Extraction.* This may be due to presence of base metal, to coarseness of the gold, alloys of the Au with Bi, Fe, Sb, etc., or to soluble sulphides present, or much kaolin or talc gangue. If preliminary washing with water and weak acid or weak alkali is ineffective, the ore is not adapted to the KCy process.

Coarse Au may be overcome by amalgamation before or after treatment.

Au alloys (Bi, Sb, Fe, etc.), require fine grinding and long contact of the solution. Roasting may be effective.

Soluble sulphides *may* be overcome by use of a Pb salt or an oxidizing agent.

Much kaolin or talc in the gangue, or much oxidized Cu minerals in the ore, are fatal to the process.

6. *Free KCy in Solution.* Use a solution containing 6.535 gms. $AgNO_3$ per litre. On 10 cc. of KCy each cc. = 1 lb. KCy per ton (2000 lbs.) of solution. To the solution to be tested add a few drops of a 5 per cent. solution of KI. Then run in the standard $AgNO_3$ solution until a permanent pale yellow opalescence of AgI appears, showing that all cyanide has been converted to $KAgCy_2$. If Zn is present an insoluble $ZnCy_2$ will slowly form as soon as the $KAgCy_2$ has formed. In that case the titration must be rapidly performed.

7. *Free KCy.* To 10 cc. of the solution add 10 cc of $KHCO_3$ solution (15 gms. per litre), and titrate as above, without the use of KI indicator. The difference between the result thus obtained and that found by a test without $KHCO_3$, gives a basis for calculating free HCy.

8. *Total Simple Cyanides.* To 10 cc. of the solution add 10 cc. of N/2 NaOH, dilute to 65 or 70 cc. Titrate with KI indicator. The result gives total KCy, HCy and K_2ZnCy_4 in terms of HCy. The amount of NaOH to be added depends on the amount of Zn compound present, but an excess is to be avoided.

9. *Ferro Ferri- and Sulpho-cyanides.* Titrate with standardized $K_2Mn_2O_8$ solution (0.3 to 0.5 gm. per litre), in H_2SO_4 solution. The reactions are:

$10K_4FeCy_6 + K_2Mn_2O_8 + 8H_2SO_4 = 10K_3FeCy_6 + 6K_2SO_4 + 2MnSO_4 + 9H_2O$.

$10KCyS + 6K_2Mn_2O_8 + 13H_2SO_4 = 11K_2SO_4 + 12MnSO_4 + 10HCy + 8H_2O$.

A known volume of the solution is titrated directly, another volume is treated with Fe_2Cl_6 the prussian blue filtered off, and the filtrate titrated. The last gives KCyS, the first both KCyS and K_4FeCy_6 in accordance with the above equations.

Ferricyanide may be determined by reducing to ferrocyanide, and titration with $K_2Mn_2O_8$.

If sulphides are present, remove by shaking with moist $PbCO_3$ before determining the compound cyanides.

10. *Zinc and Lime.* Determine as in test 4.

11. *Gold and Silver in Solution.* Evaporate one assay ton (29.2 cc.) in a small lead tray, roll up the capsule, and cupel. Alloy with Ag if necessary, and part as usual.

Analysis of Percussion Cap Composition. Jones and Wilcox. (Chem. News, LXXIV. 283.) The composition usually consists of mercury fulminate, Sb_2S_3 and $KClO_3$. The difficulties in analyzing it are obvious. The authors have found that the mercury fulminate is soluble in pure acetone saturated with ammonia, whereas the other constituents are insoluble.

An analysis can, therefore, be readily made by extracting a weighed amount upon a weighed filter, first with acetone and ammonia (which should act for 3 or 4 hours), and afterwards with water, weighing between.

A New Element—Lucium. (Chem. News, LXXIV. 159.) M. Barrien has found in monazite sand an oxide of a metal to which this name has been given. It does not form insoluble double salts with Na_2SO_4. or with K_2SO_4. It is precipitable by $Na_2S_2O_3$ also by $H_2C_2O_4$. The spectral rays approximate to those of erbium. Its oxide and salts, however are colorless. The atomic weight is calculated as 104. The use of the oxide in incandescent lighting is patented by the discoverer (ib. 212). Crookes (ib. 259) finds Lucium to be impure Yttrium.

BOOK REVIEWS.

Notes on Assaying. By P. De Peyster Ricketts, E. M., Ph. D., Professor of Analytical Chemistry and Assaying; and Edmund H. Miller, A. M. Ph. D., Tutor in Analytical Chemistry and Assaying, School of Mines, Columbia University, New York. John Wiley and Sons, New York. 1897. Rewritten and reset, 8vo., 311 pp., illustrated. $3.00.

This publication is intended by the authors to replace "Notes on Assaying and Assay Schemes," published in 1876 and revised in 1879. This will undoubtedly be accomplished, as the publication under review is up to date and contains many valuable additions.

To successfully determine the amount of metals in ores and alloys it is necessary to be familiar to some extent with chemistry and mineralogy. This necessity has been recognized through the entire work.

In many cases rapid and latest methods of determination are given. The authors claim for all methods satisfactory results after careful trial in the School of Mines assay laboratory, Columbia University.

The subject-matter may be classified under the following heads: qualitative determinations by blow-pipe and chemical analysis; quantitative determinations by assaying proper and chemical analysis; and laboratory ore-testing.

The division of the entire subject into separate and well defined parts assists the reader materially in obtaining a clear idea of special matter under consideration and the relation of one branch of work to another.

Part I. is devoted to an introduction. It comprises a description of apparatus, reagents, chemicals and various operations, such as weighing, washing, reduction, inquartation, parting and reporting. This division of the work is well illustrated and gives a clear idea of all apparatus used in weighing, sampling and conducting a fire assay. The reagents and chemicals used in the wet and dry work are classified and the formula of each is given.

The changes in weight, value, etc., produced by roasting an ore, are appreciated by few and comprehended with some difficulty. Some clear statements on this subject under roasting would have been especially valuable. Some of the points in question, however, can be found under the assay of gold and silver ores and chlorination assay for gold.

Part II. treats of the determination of metals in ores and bullion in the dry way or by assaying proper.

The charges given especially for gold and silver ores are simple, satisfactory and up to date.

The accuracy of the gold and silver assay, the method of determining gold and silver in copper matte, and the assay of silver sulphide and sweeps and the assay of coal are given special consideration. The statements upon these subjects are suggestive and valuable.

In some of the determinations of the base metals by fire methods a table is given showing results obtained by various charges as well as chemical analysis. Some definite statements might have been made about the character of the ore assayed and conclusions drawn. These would possibly have explained the low results obtained by quantitative analysis as compared with those obtained by a certain fire assay on galena.

Part III. considers the analytical methods of determining silver in bullion, lead, zinc, bismuth, copper, iron, manganese, nickel, cobalt, sulphur, arsenic and phosphorus. A scheme for the determination of silica, sulphur and phosphorus in an iron ore concludes this part. From the above list the absence of some important determinations will be noted.

Part IV. contains a most important subject, ore-testing. The attempt to determine the best method of obtaining the greatest yield of gold and silver from an ore naturally follows the knowledge of their existence. There would hardly be place in such a publication as this for the consideration in full of the various methods of treatment. The authors treat this subject from an assay standpoint, considering the methods of reaching various results on a certain test rather than the application of tests to ores. The following laboratory tests are given: mechanical assay for gold, amalgamation, chloridization assay, chlorination assay, bromine extraction test, cyanide extraction test and Russell-process extraction test.

The blow-pipe tests and schemes for qualitative blow-pipe analysis are most complete and form one of the most valuable and important features of the publication. This subject is followed by schemes for qualitative analysis.

Part V. contains valuable tables, examples and a bibliography on assaying.

Serviceable binding, good quality of paper and neat letter-press work are especially noticeable.

The difficulty of preparing a work that will meet the needs of the practical man, as well as the student, is well recognized by all. In this respect the authors have been particularly fortunate. Clear, simple statements, free from confusing technicalities, are well proportioned to ample material of a scientific nature.

Considered collectively "Notes on Assaying" is a manual of great value. It is a most admirable reference book and text-book for technical schools. W. R. A.

The Gases of the Atmosphere. The History of Their Discovery. By WILLIAM RAMSEY, F.R.S. London: Macmillan & Co., Ltd. New York: The Macmillan Co. 1896. Price, $2.00.

In this work the author has described in popular language the history of the new element argon, discovered in 1894, leading up to the same by the history of the discovery of the better known constituents of the atmosphere.

The subject-matter is presented in a clear and pleasing manner and comprises: Chap. I., The experiments and speculations of Boyle, Mayou and Hales. Chap. II., "Fixed air" and "mephitic air"—their discovery by Black and Rutherford. Chap. III., The discovery of "dephlogisticated air" by Priestley and Scheele. The overthrow of the phlogistic theory by Lavoisier. Chap. IV., "Phlogisticated air," investigated by Cavendish. His history of the composition of water. Chap. V., The discovery of argon. Chap. VI., The properties of argon. Chap. VII., The position of argon among the elements.

The author's easy style and interesting manner gives a charm to the work that should make it attractive to the scientific as well as the general public. It is particularly recommended to those who desire the knowledge but who have not had the special scientific training necessary for a proper understanding of scientific and technical literature.

The work is illustrated by wood-cut portraits of Hales, Boyle, Mayou, Black, Rutherford, Priestley, Lavoisier and Cavendish. The volume covers 240 pages on board covers. The typography is clear and the paper of good quality. J. S.

Alternating Currents and Alternating-Current Machinery. By D. C. JACKSON, C.E., and J. P. JACKSON, M. E. New York: The Macmillan Co. 718 pp., 25 tables and 321 diagrams and illustrations. Price, $3.50.

This treatise very aptly forms the second volume of the Text-book on Electro-magnetism and the Construction of Dynamos, the first having been confined to Direct Current work.

The opening chapter, devoted to the considerations which determine the form of the electro-motive-force curve produced, is followed by one

giving the various windings for alternator armatures, illustrated by numerous diagrams which aim to set forth the principles rather than present an actual working winding.

Self-induction and Capacity form the heading of Chap. III., which extends over 100 pages. Here the authors discuss the effects of these qualities on the current flow, besides giving numerous methods for measuring and determining the various other quantities involved in describing the flow of current due to an harmonic electro motive-force.

The following 70 pages are devoted to the elaboration of graphical and analytical methods of solving problems in alternating-current circuits. Although this chapter is no doubt very useful, yet in the opinion of the reviewer it might be greatly boiled down and be of still greater value to the student, if instead of presenting a multiplicity of examples the underlying principles were tersely stated.

These subjects being disposed of, facts are next presented relating to the practical construction of alternators. The questions here considered are: The magnetic circuit, field windings, the self-inductance of the armature and the various losses, besides characteristics, regulation and efficiencies.

A discussion of Mutual Induction pointing out the relations which exist between two adjacent circuits, one or both of which carry an alternating current, besides allowing the authors to present methods of measuring mutual inductance, serves as an admirable introduction to the Transformer. This branch of the subject is dwelt upon at some length, beginning with the operation of an ideal transformer, then noting the effect of copper and iron losses, with methods of determining these losses, and ending with an admirable chapter on the design of transformers.

Polyphase conducting systems and the measurement of power in polyphase circuits form the subject of a brief but very practical chapter in which special reference is made to methods employed in practice. A very extended discussion on alternating-current motors presents the principles underlying their action and adds much to the merit of the work.

A short chapter on polyphase transformers closes the work, to which are added several appendices on Resonance, Electrical Oscillations, etc.

The treatise possesses much merit, being logical in its arrangement, and the explanations and deductions being clearly stated in as elementary a manner as the nature of the subjects will permit. Data is here presented some of which can only be dug out of technical periodicals, while the rest, up to the present time, has been entirely inaccessible to the student and ordinary engineer. The main value of the book lies in its innumerable references, which give not only evidence of the great care used in its preparation, but also make it almost an encyclopedia on this subject. The authors are certainly to be congratulated on producing the first work deserving the name of text-book on this important and difficult branch of electrical engineering. W. H. F.

Mechanics of Pumping Machinery. By Dr. JULIUS WEISBACH and Professor GUSTAV HERMANN. Translated from the second German edition by KARL P. DAHLSTROM. The Macmillan Company. 1897. With 197 illustrations; 300 pages, with index. Price, $3.75.

This book carries forward the work of its distinguished German authors along the same lines as the similar section upon hoisting machinery. It

has been supplemented by adding to the original text some developments of more recent pumping practice with a certain number of illustrations.

There are six chapters. The first covers the more elementary types of water-lifting apparatus, beginning with the old well sweep, which is the immediate derivative of the simple bailing of water, and passing from that to the appliances for throwing water by scoops and the water balance. The water balance passes directly into the flash wheel and the latter into the scoop wheel, which are very completely illustrated with calculations and examples. The flash or scoop wheel passes into the chain pump and the bucket elevator, in which class of course the Noria belongs, and in its discussion certain interesting names are introduced which are novelties to most readers. The old style of cistern pump with disks concentric on the links of the chain are called "Pater-noster" pumps, or "Rosary" pumps, both of which terms seem specially felicitous bits of description. The Archimedean water screw, passing into the Dutch screw, which is really a screw elevator and applicable to handling loose material like grain, completes the appliances of the first chapter.

The second chapter takes up reciprocating pumps. The author separates pumps from other hydraulic lifting appliances by introducing as a difference their peculiarity of having the water subjected to a pressure in the operating chamber sufficient to balance or exceed that exerted by the required lift. The special features of piston and plunger pumps, single and double-acting pumps, and the characteristic features of pump valves, both in the conventional and in some unusual forms, cover the contents of the second chapter. The third is devoted to the theory of reciprocating pumps; the questions of inertia and lifting force of moving water, the wasteful resistances and the efficiency are discussed, and the bearing which they have on the volumes of water chambers, etc., are treated with illustrative examples.

The fourth chapter presents many illustrations of typical reciprocating pumps, with special reference to fire-engine practice, although it covers also the methods of operating mine pumps by water pressure and illustrates certain typical forms of American and Cornish pumps. But it does not constitute an exhaustive treatment of water-works pumping engines, although many of the fundamental principles for such engines are laid down and illustrations are presented of Gaskill, Worthington and Allis pumps. The translator appends a bibliographic reference, where the reader will find much of descriptive material to supplement the lack of the original treatise.

The fifth chapter discusses the rotary and centrifugal pump, presenting both illustrative types of oscillating pistons and of continuously-moving rotating pistons. The centrifugal pump theory is not specially difficult and is discussed at all necessary length. The final chapter covers the jet or impulse hydraulic machines using water upon water, steam upon water, air-lift pumps and siphons. There is a discussion also of spiral pumps, which is a form of apparatus but little used in the practice with which the writer is familiar.

This book will be found a convenient addition to the other books on the subject of hydraulic engineering and has been very excellently well done as a piece of book-making and translation. It leaves, however, in common with so many treatises of the same sort a species of dissatisfaction behind it, in that because it is so good in what it does do, it should not

have been better. It does not give the practical aid which is needed by the person who is actually engaged in the work of design laid upon him, and is very full and complete upon subjects which the American engineer is very unlikely to be called on to discuss. It is becoming more and more the case that hydraulic machinery, along with so many other departments of engineering, is becoming a specialty and in its subdivisions the general practitioner in need of an appliance is most likely to arrange with a specialist manufacturer to supply him what he needs. This tendency reacts to compel the specialist to know much more on the subject of his specialty than such general treatises seem to be able to include, whereby they are made unsatisfactory to him. This condition makes book-making which shall be satisfactory more difficult than it used to be, and perhaps is the occasion for the sense of disappointment which so often accompanies the examination of what are really standard works.

F. R. H.

Colliery Surveying. A primer designed for the use of students and colliery manager aspirants. By T. A. O'DONAHUE, M. E., editor of *Mining Engineering.* First-class certificated colliery manager, etc. New York: The Macmillan Company. 1896. 163 pages. Price, 80 cents.

Several accounts of the instruments and methods used in underground surveying have recently appeared in this country, but they have been written with special reference to the conditions prevailing in metal mines, and have presupposed a considerable knowledge of the principles of land or surface surveying. In this little book the aim of the author appears to have been to make his exposition of the subject complete in itself, so far as space permitted, and holding in view the fact that it is intended for beginners. He opens with a brief description of the construction and use of the ordinary draughting instruments, a resumé of the geometrical theorems and rules of mensuration usually employed, and the principles of surface surveying. Then follows a concise explanation of vernier reading and a short description of the compass and theodolite. Having reached this point, however, we regret that our anticipations on taking up the book have not been realized. While we do not lose sight of the fact that it is intended to cover only comparatively simple colliery surveying, and as such it has been unnecessary to take up the difficulties often met in highly inclined and irregular mineral deposits, still in some of the chapters brevity has been carried to excess, and several important omissions are apparent. The most serious omission is that of the methods of shaft surveying. No mention whatever is made of the delicate and often difficult operation of carrying lines down shafts, and there is only a bare reference to the connecting of the underground survey with the surface. In these matters, as in most others pertaining to underground surveying, principles are easily comprehended by those who have had some training in surface surveying. The special manipulation required underground, however, and the methods of surmounting the difficulties there encountered, should be clearly set forth in detail in any book designed for the instruction of students and beginners. We think, also, that the useful 3-tripod system of running traverses should have received more attention from the author. The chapters on leveling and on the platting of surveys are probably the most satisfactory in the book. As

the English mining terms and phraseology often differ materially from those in this country, some care is occasionally required to obtain a clear understanding of the author's meaning. In an appendix is given a series of 115 examination questions in mine surveying which may be found useful. R. P.

A Text-Book of Plane Surveying. By WILLIAM G. RAYMOND, C.E., Member American Society of Civil Engineers; Professor of Geodesy, Road Engineering and Topographical Drawing in Rensselaer Polytechnic Institute. American Book Company: New York, Cincinnati and Chicago. 12mo, cloth, 485 pages. Illustrated. Price, $3.00.

This work, as its title and the experience of the author both in teaching and practice would indicate, is a manual for the study and practice of plane surveying. Special care has been taken to present each subject in a clear and concise manner and with ample illustrations. General methods are given first in each case and followed up by presenting the subject in greater detail; a method of instruction most agreeable to both teacher and pupil, also facilitating the use of the book for reference purposes.

The book proper is divided into two parts. Book I. comprises the description of all the instruments used in ordinary plane surveying, including the more modern types, and also their elementary use, being divided into six subjects, viz.: The Measurement of Level and Horizontal Lines, Vernier and Level Bubble, Levelling, Determination of Direction and Measurement of Angles, Stadia Measurements, and Land Survey Computations.

Under the first head the illustration given of the proper position for a head chainman would seem to be rather awkward, but may have advantages not at first apparent. The numerous "Hints" and practical suggestions should be of great value to a young and inexperienced engineer. The subject of Level Survey Computations has received specially careful attention and has been most systematically arranged. It includes the description and use of the Planimeter and the Slide Rule, the article upon the latter being written by C. W. Crockett, C.E., A.M., Professor of Mathematics in the Rensselaer Polytechnic Institute.

Book II. comprises General Surveying Methods and devotes particular attention to City Surveying, Topography, Earthwork Computations, Hydrographic and Mine Surveying. The particular forms of instruments used in Hydrographic and Mine Surveys are treated under these heads, and the Plane Table under that of Topography. In connection with Topography and Mining the colored plates at the back of the book are excellent examples of maps finished as in actual practice, and are a new feature for a work of this kind.

The appendix affords numerous practical problems, such as the young surveyor is apt to meet with outside, and should be of great value for practice before going into the field.

The articles on "The Judicial Functions of Surveyors," by Justice Cooley, of the Michigan Supreme Court, and on "The Ownership of Surveys," by the author, are valuable hints to the beginner. The tables have been most carefully prepared and for their size are most valuable. The printing of the logarithmic tables upon tinted paper makes them easy of

access; large and clear type is used, and the paging is so arranged that logarithms of all numbers beginning with a given figure may be found without turning the page. Five place tables have been adopted, and the arrangement for tenths of a minute instead of for seconds, renders the book more serviceable both for practical and theoretical purposes.

T. H. H.

Elements of Geometry. By ANDREW W. PHILLIPS, PH. D., and IRVING FISHER, PH. D., Professors in Yale University. Harper & Brothers. 1896.

This important treatise makes evident that its authors have spent great pains upon revivifying the presentation of the subject to students. While the demonstrations are rigid, the method of discussion is practical, and the reasoning simple and clear.

The constructions in the plane geometry are distributed so that the student is taught how to make a figure before he is required to use it in demonstration. The definitions are also distributed as needed, but corralled in an alphabetical index. Exercises are plentiful and well selected.

"The Theory of Limits" is treated with vigor; the chapter on "Ratio and Proportion" is thorough, and throughout the work natural and symmetrical methods of demonstration are favored.

The figures are bold and varied. In diagrams and text single letters are frequently used, for conciseness, to designate lines and angles. Geometry of space is admirably illustrated by means of half-tone engravings from the photographs of actual models recently constructed for use in class-rooms of Yale University, enabling the student to see what in the ordinary diagrams he must imagine.

The work is full of spirit.

J. W. D.

Colorado. The State Agricultural College, the Agricultural Experiment Station. Bulletin 33. Seepage or Return Waters from Irrigation. Fort Collins, Colorado, January, 1896.

The above pamphlet by Mr. L. G. Carpenter, Meteorologist and Irrigation Engineer of the Station, embodies the results of measurements and gagings carried on for the last five years or more on the *Cache a la Poudre* and *Platte* rivers, with the object of determining, as closely as possible, the amount of seepage from the irrigation works back to these streams and also the nature of the flow and the conditions which influence it.

The conclusions arrived at, while only applicable, strictly speaking, to the valley in which the measurements were made, will nevertheless prove interesting reading to all interested in irrigation.

The economic questions which an acccurate knowledge of the action of seepage water from irrigation would help to settle are many, their importance at times giving rise to international dispute. As the country becomes more thickly settled, questions as to the effect on the lower stream of irrigation in the upper portions of the valley will become more numerous.

One of the interesting results arrived at in these experiments was that the effect of temperature on the flow of the ground water could not be neglected. The temperature was determined by three sets of soil thermometers buried in various kinds of soil at depths of three and six feet, and the conclusion was that "with the range of temperature at the depth

of six feet, other conditions remaining the same, one-third more water would flow in August than in March, and at a depth of three feet nearly one-half more."

The amount of flow depends upon so many factors that no definite results could be arrived at. It was found, however, to be approximately proportional to the irrigated area. It depends but slightly upon the rainfall, and even then only that which falls on irrigated or already saturated land.

The rate of flow of the seepage water through the soil was found to be very slow, varying between 10.2 feet per day for sandy clay to 22.4 feet per day for coarse sand. In this the results agree very closely with those arrived at in India and elsewhere.

The commercial value of this seepage water is no small item, amounting in the valley of the Poudre to from $300,000 to $500,000 at the least, and in that of the Platte from $2,000,000 to $3,000,000. It is also of corresponding importance in the valleys of Clear Creek, St. Vrain and others.

A map of the Cache a la Poudre and one of the South Platte valley, together with several diagrams showing some of the results graphically, help to explain the text and add much to the usefulness of the report.

C. McK. L.

The Cell in Development and Inheritance. By EDMUND B. WILSON, PH. D., Professor of Invertebrate Zoölogy, Columbia University. The Macmillan Company: New York and London. 1896. Columbia University Biological Series IV., 8vo., 371 pp., illustrated. Price, $3.00.

This book is the fourth in the Columbia University Biological Series, and is the outcome of a course of general lectures delivered at Columbia University in the winter of 1892–'93. Its scope is, however, far wider than the limitations of a course of lectures would allow, for to the student it traces the recent advances in cellular biology, while at the same time it gives to the general reader who would keep abreast of scientific thought a comprehensive and comprehendable idea of the position of the germ cell in development.

What Darwin's theory of development revealed to the scientific world of the preceding generation is complemented by the discoveries concerning the nature of the germ cell made during the past twenty years.

The theory summed up briefly is that a single cell, or rather two cells, one from the male and one from the female, "may contain within their microscopic compass the sum-total of the heritage of the species.

The history of the research upon this subject, the experiments and refuted theories, and the various steps of progress by which the problems of evolution have been reduced to problems of the cell, are described by Dr. Wilson in clear English and in a literary style that few scientific writers have at their command.

A glance through the book at its fine plates, all of cells, showing their structure, the phenomena of their division, their mode of origin and their union in fertilization, might lead one to think that the book was written exclusively for a class of specialists; so exhaustive and detailed are the illustrations. But the reading matter on the problems of heredity and variation will interest a larger class of thinkers, and will present to the

general reader the idea that life is a continuous stream, and that "an uninterrupted series of cell division extends backward from existing plants and animals to that remote period when vital organization assumed its present form."

Dr. Wilson has written from Weismann's point of view, showing the organic connection between the theory of evolution and the cell theory.

The bibliography is very fully and carefully worked out, and for the greater convenience of the student a list of the works of chief importance bearing on the subject has been appended in each chapter. No original work of the kind has heretofore appeared in English, and Dr. Wlson's presentation of the subject will be an invaluable aid to the students of cellular biology. S. E. J.

ALUMNI AND UNIVERSITY NEWS.

HAVEMEYER HALL AND THE ENGINEERING BUILDING.*

The corner stones of Havemeyer Hall and the Engineering Building were laid on the fourth of November, in the presence of the Trustees, the donors of Havemeyer Hall and the heads of the departments which are to occupy the buildings. Bishop Littlejohn officiated at the laying of the corner stone of Havemeyer Hall, and after the stone had been laid by Mrs. Kate B. Belloni, a daughter of the late Frederick Christian Havemeyer, in whose memory the building is given, President Low delivered the following address:

Gentlemen of the Trustees, Ladies and Gentlemen:

Havemeyer Hall, the corner stone of which has just been laid, is to be the home of the Chemical Department of Columbia University. Temporarily it will give shelter, also, to the Department of Architecture and to the Department of Metallurgy; but the day is not likely to be far distant when the Department of Chemistry will need all the accommodation it supplies. It is fitting that one of the main angles of our entire group of buildings should be buttressed on this science. I remember well that when the National Academy of Sciences met in this city, a few years ago, Professor Pickering, the astronomer, of Harvard University, displayed photographs of the spectra of stars that are out of sight to the naked eye. Professor Brewer, of Yale University, in talking with me about this display, remarked that if he had been asked twenty years before which science of the whole range of science was "of the earth, earthy," he would have replied without hesitation, chemistry; because, unless you could handle a substance, how was it possible to tell what entered into its composition? Yet here we are, he added, discovering the chemical composition of stars that we cannot even see! Thus chemistry bears emphatic testimony to the unity of the universe, and, with its companion sciences of astronomy and physics, is helping us, day by day, to read. even in the farthest reaches of space, "what is still unread in the manuscripts of God."

If, on the other hand, you will pass up and down the chemical museum that has been created and arranged for this University by Dr. Chandler, you will be astonished to perceive how chemistry is related, in one form or another, to the daily necessities of life and to almost every imaginable industry and art. Food and drink, in all their forms, and the air we breathe, are subjects of chemical analysis; so that in these latter days chemistry is the handmaiden of medicine no less than of the industrial arts.

I recollect that a prominent steel manufacturer said to me, not long ago, that he had

* Reprinted from *University Bulletin.*

made steel for two years out of the waste heaps of his neighbors' factories, because he had been the first to employ a trained chemist as a part of the regular force in his establishment. The industrial progress of modern Germany may almost be said to rest primarily upon chemistry, so important a factor is it in all German industries. Similarily, I am glad to believe that the generous donors of Havemeyer Hall have thought it to be, in an especial sense, a fitting memorial of the late Frederick Christian Havemeyer to erect a home in this University for the Department of Chemistry, because the industry of the refining of sugar rests so immediately upon this science. Havemeyer Hall stands, also, in a fortunate neighborhood to the Engineering Building, for the laws of mechanics, as applied by the engineer to the manipulation of the raw sugar and the various syrups, have been only less influential than chemistry in cheapening the industrial processes involved in sugar refining. The day will come in the United States, I am confident, when the employment of trained chemists will be as common in the manufacturing industries of the country as it is in Germany. It is, therefore, an eminently gracious and graceful thing for men to do, whose fortune rests largely upon the advances that chemistry has made possible in the development of their business, to give to this University the means of equipping young men for service as chemists in all the manifold ways in which chemists may serve the community and the country. The field of the chemist's labor, as I have shown, is as wide as the universe, and his opportunities of service as various as the industries of men.

To prepare young men for such a service this building has been given, and Columbia has pledged herself to the donors to make it as highly useful as it is in her power to do. To redeem this pledge she will put forth every effort, because she well understands that only so can she make Havemeyer Hall a worthy memorial of the useful life of Frederick Christian Havemeyer.

At the conclusion of his address President Low called upon Professor Chandler, who said:

Mr. President, Trustees of Columbia University, Ladies and Gentlemen:

I can not express in words the pleasure and satisfaction which it gives me to enjoy the privilege of being present to-day at the laying of the corner stone of this magnificent chemical building. Ever since the Chemical Department of the School of Mines opened its first laboratory, for twelve students, in the cellar of the old building at Forty-ninth Street, thirty-two years ago, on November 15, 1864, I have looked forward with hope to the day when suitable accommodations should be provided at Columbia for this my favorite science.

And now my expectations are to be realized. The finest and most complete chemical building in the world is now rising upon the most favorable spot on New York Island, and Columbia University will soon be able not only to offer every facility for the study of chemistry, in all its branches, theoretical and applied, but also to invite graduate students to enter its well equipped laboratories to prosecute original investigations.

It is a great pleasure to me that this gift should come from a family which stands so high in this community, members of which have long been my friends, and some of whom have been pupils in our laboratories, and it is extremely satisfactory that this building is to bear the name of Havemeyer Hall, and to stand as an enduring monument to Mr. Frederick Christian Havemeyer, who laid the foundation of one of the most important and extensive chemical industries of this country.

As the representative of the Chemical Department of Columbia University, I promise to do everything in my power to make the usefulness of this building equal the generosity of its donors.

The Rev. Dr. Coe officiated at the laying of the corner stone of the Engineering Building, and Professor Crocker, representing the Department of Electrical Engineering, laid the stone. Henry S. Munroe, E. M., Ph. D., Professor of Mining, spoke as follows of the purposes to which the building is to be devoted:

We are to-day to lay the corner stones of two more of the group of beautiful buildings planned for the new home of Columbia University. The Library Building, with its classic porch, dominating the group with its lofty dome, is appropriately devoted to literature, philosophy and law, representing the historical university faculties. The four great buildings which we see rising about us, of a more modern type of architec-

ture, assigned to natural history, physics, chemistry, and engineering, offer striking testimony to the place that science has conquered in the modern university. Formerly it was accepted without question that "the proper study of mankind is man." In this age we have begun to look about us, and we now recognize that the study of mankind is incomplete without the study also of his environment. The world in which we live, and the other worlds by which we are surrounded; the animals and plants inhabiting the world with us, and those which lived here in ages past; the laws of the universe; the forces of nature offer boundless fields for the student.

The renaissance architecture of these scientific buildings typifies the new life given to the university by science. Not only does education gain by the enlargement of the field of study, but methods of investigation borrowed from men of science, and applied to the study of language, of philosophy, of history and of law, have enabled these to make a greater advance in the last few decades than in centuries before.

The dedication of a university building to engineering posesses great significance. It shows how far Columbia, in common with other American institutions of learning, has advanced beyond the narrow view of the mediæval university which still obtains in Europe. It is a recognition of the truth that science is not only to be followed for its own sake, for the pleasure and excitement of conquering new fields, but the scientific studies with a definite object in view, investigations that will benefit mankind, are even more worthy, and may properly find place in an institution of higher learning.

The erection of a building for engineering among the first of Columbia's new halls is an appropriate recognition of the fact that Columbia was one of the first colleges in this country to add engineering studies to its curriculum, being anticipated in this by Union, Harvard, Yale and Michigan only. Columbia was the first to establish a course in mining engineering; she was among the first to give instruction in sanitary engineering, in electrical engineering, and in these and in many other respects Columbia has taken the lead in engineering education.

In Europe the universities for the most part hold themselves aloof from the schools of technology and engineering, and there is a very strong feeling there among the scientific men connected with the universities against engaging in useful work, against applied science. Recently a distinguished German mathematician has uttered a protest against this feeling. He claims that applied mathematics is worthy the attention of the student of pure science, and that he will be benefited rather than harmed by practical problems and practical applications. His protest has taken a peculiar form, as if the professor hardly dared to face boldly the criticisms of his colleagues should he turn his mathematics to a purpose altogether useful. The distinguished savant gravely applies himself, with the aid of higher mathematics, to the investigation of the laws governing the movement of a spinning top!

It is fortunate for us that there is in this country but little of the prejudice against applied science that is found abroad, and against which Professor Klein finds it necessary to protest. At Columbia pure science and applied science work together in harmony and with mutual advantage.

This building is to be equipped with laboratories for the study of practical problems in mining, civil, mechanical and electrical engineering. Problems of the greatest importance to the world and to society await solution in these various branches of engineering.

In an address, a year or so ago, before the Alumni of the School of Mines, Dr. Raymond showed that the world has begun to save money and to grow rich and comfortable only within the present century. He showed that this prosperity dates from the time that steam began to take the place of human energy. The use of steam has multiplied the power and efficiency of the race. With its aid we are forcing the earth to give up her treasures of coal, oil, gas, useful and precious metals, while agriculture, fisheries and manufactures have developed as never before. When we compare the condition of the peasant and the laboring man of the Middle Ages with the comparative comfort enjoyed by men of similar position to-day we realize the advance that has been made. But much remains to be done. Owing to our limited and imperfect knowledge, we waste, of necessity, vastly more of the wealth that the earth furnishes us than we utilize. For example, it is estimated that for every ton of anthracite coal sent to market one and a-half tons are lost in mining and in preparing the coal for use. Last year the coal product of eastern Pennsylvania was worth at the mines about $90,000,000. The loss was then about $135,000,000. It is estimated also that we utilize but about one-eighth of the power stored up in coal when we burn it under boilers to furnish steam.

In engineering construction, to guard against possible imperfection in material and unknown sources of weakness, we are accustomed to employ "factors of safety," and to use three, four or five times as much material as rigid calculations, based upon the best obtainable data, would seem to demand. These are probably extreme cases. The loss in mining is not often as large as in Pennsylvania, where the conditions are unfavorable to economic working. Water power, steam power and electric energy are more fully utilized than calorific power. "Factors of safety" will always be necessary. Nevertheless, similar instances of waste of material and loss of energy meet us on every hand, and it is not too much to say that we loose or waste vastly more of nature's wealth than we utilize. Every discovery in applied science tends to lessen these losses. The laboratories which it is proposed to equip in his beautiful building have thus important work to do, and if properly used they may render most important service to mankind. When we consider what has been done for the race in the present century, it seems that we have only to continue this good work and use more carefully nature's bounty to bring about the utopian dreams of the philanthropist.

The first object of this building and these laboratories is, however, the training of young men as engineers. In addition to the waste due to our imperfect knowledge, even greater loss and waste results when mines, manufactories and public works are in incompetent hands. The useful work that is now being accomplished by the thousand young men who have been graduated from the School of Mines, and the work that will be done by the thousands that will come after them, is sufficient warrant for the large sums spent by this University on their education, and the still larger sums she is proposing to spend as trustee of the wise and far-seeing men who have put and are putting their wealth into her hands. The money spent in the training of these young men is well spent, and yields returns that cannot be measured. In this building will be trained mining engineers to develop and operate mines, to furnish for our use the treasures of the earth upon which modern civilization is founded—coal, to take the place of human energy and relieve the race from drudgery, and the metals, the use of which marks the difference between the primitive savage of the Stone Age and civilized man with all the comforts and luxuries of the nineteenth century. In this building will be trained civil engineers to construct and take charge of public works, roads and bridges, railroads and canals, to improve our rivers and harbors, to superintend great municipal works, to irrigate deserts, to drain swamps and fit waste places for human habitation. Here will be trained electrical and mechanical engineers, who harness the mighty forces of nature and compel them to our service, to move us when we will, to bring merchandise for us from the uttermost parts of the earth, to fashion wood and metal and other products of nature for our service.

It is fortunate for the School of Mines and the School of Engineering that they are associated with a great university. This association forces them to maintain high ideals and a high standard of scholarship. The student of applied science has the advantage of university instruction in pure science and mathematics, and the foundation for the professional studies is thus well and broadly laid. The contact with men who are seeking liberal culture cannot fail to extend the horizon and broaden the views of the technical student, and we hope may induce him to seek first a liberal education before entering upon his professional studies.

On the other hand, the demands of the courses in applied science in the departments of mineralogy, geology, chemistry and physics have necessitated the splendid equipment of laboratories and museums now possessed by the University in these branches of science. Thus each gains by the presence of the other, and in their union lies the strength of the typical American university—Columbia.

The following papers and documents were deposited in the corner stones: charter and acts relating to the University; statutes of the University and by-laws of the Trustees; programme of the Dedication proceedings, historical sketch of the University, and addresses delivered upon the Dedication; general catalogue of the officers and alumni; catalogue for the year 1895–96; annual reports of the President and Finance Committee for 1896; circulars of information of the Departments of Chemistry, Architecture and Metallurgy and of the Departments of Civil, Mining, Electrical and Mechanical Engineering; views of Havemeyer Hall and the Engineering Building; a copy of the last number of the

University Bulletin, and newspapers of the day; and also in the corner stone of Havemeyer Hall a copy of the letter of Mr. Henry O. Havemeyer of April 7, 1896, offering to present to the University a chemical building, to be known as Havemeyer Hall in memory of the late Frederick Christian Havemeyer, as a gift from Charles H. Senff, his nephew, Frederick C. Havemeyer, Theodore A. Hayemeyer, Thomas J. Havemeyer and Henry O. Havemeyer, his sons, and Kate B. Belloni and S. Louisa Jackson, his daughters; together with copies of the agreement between the University and the donors, and of the resolution of thanks adopted by the Trustees.

THE SCHOOL OF ARCHITECTURE.

The establishment of the Department of Architecture as an independent school at the beginning of the present year was only the formal recognition of the separation from the other departments in the School of Mines, which had already taken place. The action of the School of Mines Faculty a year ago in consenting that the students in Architecture should no longer attend the instruction in Physics, Chemistry, Applied Chemistry and Geology completed an isolation which had begun several years before, when, as Professor Trowbridge suggested, students should have special instruction in Architectural Engineering, instead of attending his own lectures. This change enabled them to concentrate their time and attention on the things they most needed to know, and proved so beneficial in practice as to encourage the idea that those branches of Applied Chemistry and Geology that were most pertinent to building operations could be pursued to better advantage if separated from the general courses of lectures in these subjects. This involved, of course, the sacrifice of many interesting topics, but it was the only way of gaining time for the expression and development of the more strictly professional work. It was assumed that the knowledge of physics and chemistry required for admission to the School would suffice for the intelligent prosecution of these special studies.

The result seems to be justitying these expectations. A new course of lectures, one a week, running through three years, has been established, under the name of Building Materials. This accompanies and illustrates the choice in specifications. Both are attended by all the students in the first three years of the School, and as Ironwork is taken up one year, Masonry the next, and Woodwork the next, each class covers all these topics, though in a varying order of succession. As each material comes up it is exhaustively discussed, from the point of view of geology and chemistry, its mode of manufacture, practical applications and uses, and the means of preserving it from decay; the work is thus classified according to the subject-matter, or according to the sciences which bear upon it. The scientific instruction is thus rendered more particular and pertinent.

The present year is the year for Masonry. The new course is mainly in the hands of Mr. Warren, and is an expansion of the instruction that formerly he had to crowd into his lectures on Specifications. These, in turn, being relieved from this burden, themselves receive a fuller development. But his work is supplemented by all the resources of the Uni-

versity. After two or three elementary lectures in Geology, Professor Kemp contributed five lectures on Building Stones, and a little later a lecture on Clay. Mr. Ries gave a lecture on Brick-making, and Mr. Vulte and Professor Ricketts have promised to follow with lectures on Cements and Artificial Stones. Other professors in the Schools of Chemistry and Civil and Electrical Engineering have promised also to lend a hand when their assistance is needed. It seems, then, as if the formal separation from the scientific departments, instead of diminishing the amount of scientific study, and making the School of Architecture a "mere School of Art," as some of its friends feared might happen, is really working to give it a greater enjoyment of the advantages of its position than it had before. These relations of comity and good neighborhood, and the voluntary service they stimulate, are more efficient than the mere formal relations they have superseded. These exercises also take less of the students' time, which is a great gain, and as each topic comes round only once in three years they impose no greater tax upon the abundant good-will and generosities of these auxiliaries than in its abundance it seems well able to bear.

ELECTRICAL ENGINEERING DEPARTMENT.

The rearrangement of some of the courses in this department has shown the wisdom of giving to the second-year men throughout the entire year instruction in the fundamental principles of Electrical Engineering, this being carried on by Professor Crocker and Mr. Freedman. By bringing the men thus early into contact with the officers of this department, they not only become more familiar with the lines which they are to follow in the future, but also see the importance and bearing of the dependent subjects which they are pursuing and have in this way their interests augmented. Some of the lecture courses in the third and fourth years have been greatly improved by the introduction into them of suitable text-books. Professor Crocker's book on "Electric Lighting" is being used with much success in his courses in Electric Lighting and Electrical Engineering, and the advance material for the second volume is being freely read in his fourth-year courses in Eectrical Engineering.

The course in electrical measurements by Mr. Freedman has been much facilitated by the use as a text-book, of Nipher's "Electricity and Magnetism," thus obviating the necessity on the part of the students of taking as many notes as was formerly necessary in this subject. Much more ground can be covered and much more satisfactorily than by giving this course entirely by lectures.

Mimeographic notes covering the mechanical, as well as many of the electrical points in the construction of dynamos and motors, have been read with satisfaction in the course in Dynamo Practice given by Professor Crocker and Mr. Sever.

Mr. Freedman is preparing a set of notes to cover the discussion of telephone and telegraph practice in this country, as the two subjects are in many details similar and no book on either of these subjects is at all suitable for use in instruction.

The third-year laboratory work has been much improved by the introduction of a definite set of experiments outlined in mimeographic notes, these experiments covering the investigation of the actions of direct cir-

cuit dynamos and motors. Close supervision of the students' work and insistence upon accuracy in results have done much towards improving the quality of the work carried on in this course. The fourth-year instrumental work under Mr. Freedman and Mr. Sever has been much improved by the use of printed forms for the recording of results, these indicating clearly the method of presenting the results of the experiments. Mr. Freedman is preparing a set of notes to cover this work. The department has purchased a 10-horse power 3-phase General Electric alternating-current motor, a 1-horse power Fort Wayne Synchronous alternating-current motor, and has been presented with a W. P. 30 General Electric Co. railway motor.

Besides these machines there have been presented to the department a number of small appliances for its use or for filling the cases which will be placed in our electrical museum in the new building.

There will be needed at the new laboratory a 40-horse power alternating-current dynamo and a 50-horse power direct-current dynamo, neither of which have as yet been obtained.

The thesis work is well advanced, some of the subjects being as follows: "Investigation of the action of a special form of circuit breaker." "Effect of heat upon insulating material." "Test of a storage battery station." "Test of a motor driven manufactory." "Investigation of open and closed magnetic-current transformers.

G. F. SEVER.

THE ENGINEERING SOCIETY.

The officers of the Engineering Society for the current year are: President, Frederick M. Holbrook, E. E.; First Vice-President, Charles E. Rogers, C. E.; Second Vice-President, William S. Davidson, E. M.; Secretary, George S. Brackett, E. M.; Treasurer, Hanford C. Judson, E. E.; Editor of the Year-Book, Alexander S. Farmer, C. E.; First Assistant Editor, Ignatius O'Reardon, C. E; Second Assistant Editor, James B. Humphreys, E. E.; Honorary President, Professor Frederick R. Hutton, E. M., Ph. D.

The condition of the Society, numerically, financially and enthusiastically, was never so flourishing as at the present time—the twelfth year of its history. There are now enrolled 107 active members, 338 associate members and 22 honorary members.

Thus far during the year the following lectures have been delivered before the Society:

November 4, 1896.—*The Mechanical Engineering of the Street Railway Problem.* By Professor Frederick R. Hutton.

Professor Hutton explained by the aid of numerous lantern slides all of the street-railway systems now in use, together with the advantages and disadvantages of each. He refrained, however, from expressing an opinion as to the precise solution of the problem, since the conditions and requirements of traffic were so various that a general solution was indeterminate.

Mr. George F. Lever presented a very interesting discussion of the paper.

November 18, 1896.—*The Water Works of Brooklyn, N. Y.* By Richard W. How, Jr. (*C. E.*)

Mr. How described by the assistance of charts and photographs both the present state of the works and the extensions proposed or in process.

December 2, 1896.—*The Central Station vs. the Isolated Plant.* By Mr. Max Osterberg, E. E., A. M.

Mr. Osterberg showed that from an economical standpoint a system employing many isolated plants for electric lighting in many cases presented advantages over the central station of no inconsiderable importance.

Professor F. B. Croker supplemented the paper by citing a problem which he had some time previously worked out, in which the same principle of economy was manifest. He had reference to feeding small low tension sub-stations distributed through a city from a remote source, generating electrical energy at high tension.

January 13, 1897.—*A Talk on Ship Building.* By Mr. Lewis Nixon.

Mr. Nixon outlined and carried his auditors through the process of the building of a ship from the time of the letting of the contract until the trial trip and final acceptance by the owners. The scope of this lecture represented a new departure in the work of the Society, and it is to be hoped that Columbia may in the future comprise this subject in its curriculum.

The principal work accomplished by the Society aside from the papers and lectures has been the revision or really the reconstruction of its constitution to meet the changed and increased requirements due to the Society's growth and development.

On account of the readjustment of the university departments, the name has been changed from "The Engineering Society of the School of Mines" to "The Engineering Society of Columbia University."

A committee has been intrusted with the work of designing an appropriate "shingle" or seal and certificate of membership, which will add greatly to the dignity of the Society and will be a momento which in after years will recall to a graduate most pleasant reminiscences of a membership in an organization which has for its object the development of engineering knowledge and tastes and to bring the undergraduate engineer into contact and sympathy with those who have preceded him and who have already been successfully grappling with engineering problems as they present themselves in actual life.

UNIVERSITY BULLETIN.

The *University Bulletin* is issued by the authority of the Trustees of the Columbia University. Its purpose is to give a summary of important university and faculty legislation, to record the scientific and literary work of the officers of Columbia University, to furnish information with regard to original investigations that are in progress, to indicate the subjects that occupy the attention of the advanced seminaries, and to give other general information that may be either of immediate interest to inquirers, or of permanent value as a matter of record. The *Bulletin* will appear at intervals of about two months during the college year, and, until further notice, will be sent free of charge to such alumni of the University as may signify their desire to receive it.

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Four hundred Students of Columbia School of Mines have been instructed in t Woodbridge School. Also a large number have been prepared for Massachusetts I stitute of Technology, Stevens Institute, Sheffield Scientific School, Lawrence Sci tific School, Troy Polytechnic Institute, Cornell University, and the Classical, Medi and Law Departments of Harvard, Yale, Columbia and Princeton.

VOL. XVIII. No. 3. APRIL, 1897.

THE SCHOOL OF MINES QUARTERLY.

A

JOURNAL OF APPLIED SCIENCE.

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CONTENTS:

Egleston Minute of the Alumni Association of the School of Mines..... 193
Notes on Air Compressors. By Robert Peele..... 196
Puzzolana and Its Practical Use. By Josef Zervas..... 226
Principles of Electrical Distribution.—II. By Francis B. Crocker..... 240
Explorations in the Gold Fields of Western Colombia. By F. C. Nicholas..... 259
An Introduction to the Study and Experimental Determination of the Characters of Crystals. By Alfred J. Moses, Ph.D..... 266
Devereux Prize..... 288
Abstracts in Metallurgy. By Joseph Struthers, Ph.D..... 289
Book Reviews..... 296
Alumni and University News..... 303

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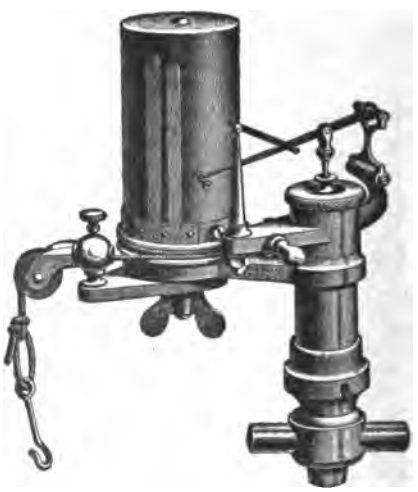

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THE

SCHOOL OF MINES QUARTERLY.

VOL. XVIII. APRIL, 1897. No. 3.

EGLESTON MINUTE OF THE ALUMNI ASSOCIATION OF THE SCHOOL OF MINES.

The Board of Managers of the Alumni Association of the School of Mines appointed a committee, at a recent meeting, to take action commemorative of the retirement of Professor Thomas Egleston from active service in the chair of Metallurgy and Mineralogy in the University. That committee consisted of Messrs. Wm. Allen Smith, '68, W. B. Parsons, '82, H. K. Masters, '94. Their action, a minute and appended resolutions, has been handsomely engrossed, and partly illuminated, and has been transmitted to Professor Egleston. Their action is reported here for record and for general information.

The Alumni Association of the School of Mines of Columbia College, in view of the retirement from active work of Professor Thomas Egleston, E. M., Ph. D., LL. D., the senior professor in the School of Mines of Columbia University, has adopted the following minute:

Profesfor Egleston was the originator of the School of Mines, and its establishment in 1864 was brought about by his foresight, energy and courage. Although his plan was received with quick sympathy by President Barnard, yet the College had at that time neither the funds nor the special instructors needed for such a school. Professor Egleston, it may fairly be said, furnished both.

He literally went begging among his friends for the needed funds, and he began his work with no assurance of compensation; and it was due entirely to his exertions and persuasion that Professors Chandler and Vinton were induced to join with him in the enterprise of starting the School of Mines. He was the indomitable pioneer who opened the way and laid the foundation for what is to-day the foremost school of applied science in the country. Moreover, the establishment of the School of Mines marked the opening of the new and broader life of Columbia, which has culminated in the University with its brilliant prospects.

The same qualities which Professor Egleston showed as a pioneer have characterized his course as an instructor; energetic, prompt and faithful, in sickness and in health, he has kept straight on his course for a third of a century, during most of that time performing the work usually done in schools of equal proportions in this country and abroad by three men, filling the chairs of Mineralogy, Iron Metallurgy and General Metallurgy. He introduced the requirement of metallurgical "projects," which have resulted in much practical good to the students. He has continued as he began, indefatigable in laboring to impart complete scientific instruction in his departments and in assisting the students committed to his charge. It is therefore

Resolved, That the Alnmni Association of the School of Mines, hereby records its full appreciation of the lasting debt due to Professor Egleston for his long and faithful and unselfish devotion to the cause of scientific instruction.

Resolved, That the best wishes of the Alumni of the School of Mines accompany Professor Egleston, and their congratulations are tendered to him upon a grand work nobly achieved.

Resolved, That this minute be entered in full upon the records of the Alumni Association; that it be published in the SCHOOL OF MINES QUARTERLY, and that a copy be sent to Professor Egleston.

WM. ALLEN SMITH, 1868.
WM. BARCLAY PARSONS, 1882
HARRIS K. MASTERS, 1894.
Committee of the Alumni.

February 5th, 1897.

35 WASHINGTON SQUARE,
NEW YORK, March 30th, 1897.

To W. ALLEN E. SMITH, E. M.
W. BARCLAY PARSONS, C. E.
HARRIS K. MASTERS, E. M.
} Committee of the Alumni of the SCHOOL OF MINES.

My Dear Friends:

I received, on Saturday evening last, the very handsome engraved minute of the Alumni Association of the SCHOOL OF MINES. If anything could temper the regret which I feel at the necessity of giving up what has been the great pleasure as well as the work of my life it would be such an expression of feeling from the graduates of the school whose committee represents all the years that I have labored in it. None know better than they how the work has been done.

The good of the school and the welfare of its graduates has so long been my first thought, and their success my great pride, that I find it difficult to realize that I no longer have the power to help either student or graduate, which is a source of real sorrow to me. The success of the school as a school is owing to the very earnest work of the many who have been engaged in teaching in it, and the high standard of the work of its graduates. Its reputation outside of the City of New York depends entirely on its graduates. It is the great body of the Alumni, to whom we can all point with pride, who make known, both at home and abroad, what the standard of the school is.

It has always been a great gratification to me to know that, while my duty was to the students, that I might some day be able to be of service as an alumnus. I have always felt that an alumnus had a claim to my best endeavors to help him, if I could, no matter in what quarter of the globe he lived, or whether he asked for it or not. The friendly intercourse that I have had with the graduates is a large part of the brightest memories of my life. Such a mark of appreciation of my work as you have sent to me from them is very grateful to me, now that I am laid aside from active duty, and I most heartily reciprocate their kind wishes.

Yours very sincerely,

THOS. EGLESTON.

NOTES ON AIR COMPRESSORS.*

By ROBERT PEELE.

Part First.

TABLE OF CONTENTS.

	PAGE.
Introduction	196
General Structure of Compressors	198
Compressors driven by steam power	198
Simple, duplex and compound	202
Method of operation of steam-driven compressors	203
Dimensions of air cylinders	205
Compressors driven by water or electric power	206
The Compression of Air	207
Principles	208
Methods of compression	209
Systems of absorbing the heat of compression	210
Wet Compressors	211
Introduction of water in bulk	212
Use of spray injection apparatus	213
Dry Compressors	214
Water jackets	215
Method of circulating cooling water	215
Piston Clearance in Air Cylinders	216
Effect upon the capacity of the compressor	217
Dry *versus* Wet Compressors	218
Disadvantages of water in air cylinder	219
Effect of water upon the compressed air	221
Compound or Stage Compression	222

For mining and other purposes compressed air forms a convenient and valuable means for the transmission of power. The conveyance of steam to considerable distances involves great losses from condensation in pipes, and in employing it underground for pumping engines, hoists, etc., other difficulties are often encountered. Prominent among these difficulties is the disposal of the exhaust steam, which, if discharged into the mine workings, increases the temperature and amount of moisture in the air, tending to cause more rapid deterioration of the timbering, softening and slacking off the walls of the workings, and to render the mine

* As this outline is intended particularly for the use of students in mining engineering much has been left unsaid as regards the theory of air compression, the important uses of the indicator in studying the behavior of air during compression, and various details of construction and proportions of parts which fall properly within the province of the mechanical engineer.

atmosphere uncomfortable and unwholesome for the miners. The presence of hot steam pipes in the narrow compartments of shafts is also objectionable. Loss from condensation in long lines of steam pipe is unavoidable. This loss may be diminished by carefully covering the pipe with good non-conducting material, but even with the best covering the effective pressure at the underground engine is seriously reduced, and very uneconomical working is the result.

Compressed air, on the other hand, may be conveyed long distances with a very small loss of pressure, and is easily distributed for application to a variety of industrial purposes for which steam would not be practically available. In mining compressed air is employed mainly for operating machine drills, also for driving small underground hoists in confined workings, and even for underground pumps, though thus far to a limited extent. Coal cutters, for the mining of bituminous coal, are frequently operated by compressed air. The occasional use of compressed air locomotives in collieries and in tunneling operations on a large scale furnishes an example of its capacity for storing power. Electricity is often cited as a rival or competitor of compressed air in the field of mining, as both possess characteristics which make them particularly convenient in connection with underground work. Two things should be borne in mind, however; first, that the spheres of usefulness of these two power transmitters are not identical; second, that compressed air is not merely a means of transmitting power, but fulfills incidently other important functions. Conspicuous among these is its great practical service underground as a ventilating agent. The exhaust from machine drills, or other machinery, is of positive benefit in adding large volumes of fresh air to the working places of mines, just where ventilation is most needed. The introduction of compressed air—together with that of dynamite—has made possible the rapid construction of long railroad and mining tunnels which, without these aids, would have been greatly delayed or even wholly impracticable. Another feature of compressed air is that it is always ready to do its work, and aside from leakage from transmission pipes, which should be preventable, suffers no loss nor diminution of power when not in actual use. For performing work *intermittently*, at a distance from its source, it has no rival.

Up to the present time no perfectly satisfactory electric rock

drill has been invented. Air drills, though they are far from being economical, considered simply as machines, fulfil their purpose admirably, and in operating them compressed air finds one of its most important applications. The high speed of electric motors, as ordinarily constructed, is objectionable for many kinds of service, and for driving pumps and hoisting engines must be reduced by gearing. Moreover, the introduction of electric machinery into collieries is attended with some risk of exploding fire-damp, on account of sparking at the motor brushes and from the rupture of conductors. These dangers have not yet been entirely obviated, and lead many colliery operators to hesitate to adopt electric transmission of power.

Although by virtue of its numerous successful applications, electricity has become for many purposes a competitor of compressed air, the field is broad and there is room for both.

General Structure of Compressors.

An air compressor consists essentially of a cylinder in which atmospheric air is compressed by a piston, the power for driving which may be derived from steam, or water, or even electricity. The air cylinder is usually double acting, and as commonly constructed is provided with inlet and discharge valves in each cylinder head. Before considering the operation and various appurtenances of the air cylinder, it will be well to look into the general mechanical structure of the compressor and the methods of applying the power.

Classification of Steam-driven Compressors.

A. "Straight-line" type, in which a single horizontal air cylinder is set-tandem with its steam cylinder, and provided with two fly-wheels. This pattern is almost invariably adopted for compressors of small size. Fig. 1 shows in plan and longitudinal section an Ingersoll-Sergeant straight-line compressor.

B. Duplex type, in which there are two steam cylinders, coupled at 90° to a crank shaft carrying a fly-wheel, and each driving an air cylinder. Fig. 2 shows a Rand duplex compressor.

C. Horizontal, cross-compound engines, each steam cylinder set tandem with an air cylinder as in *B*.

D. Vertical, simple or compound engines, with the air cylinders set above the steam cylinders.

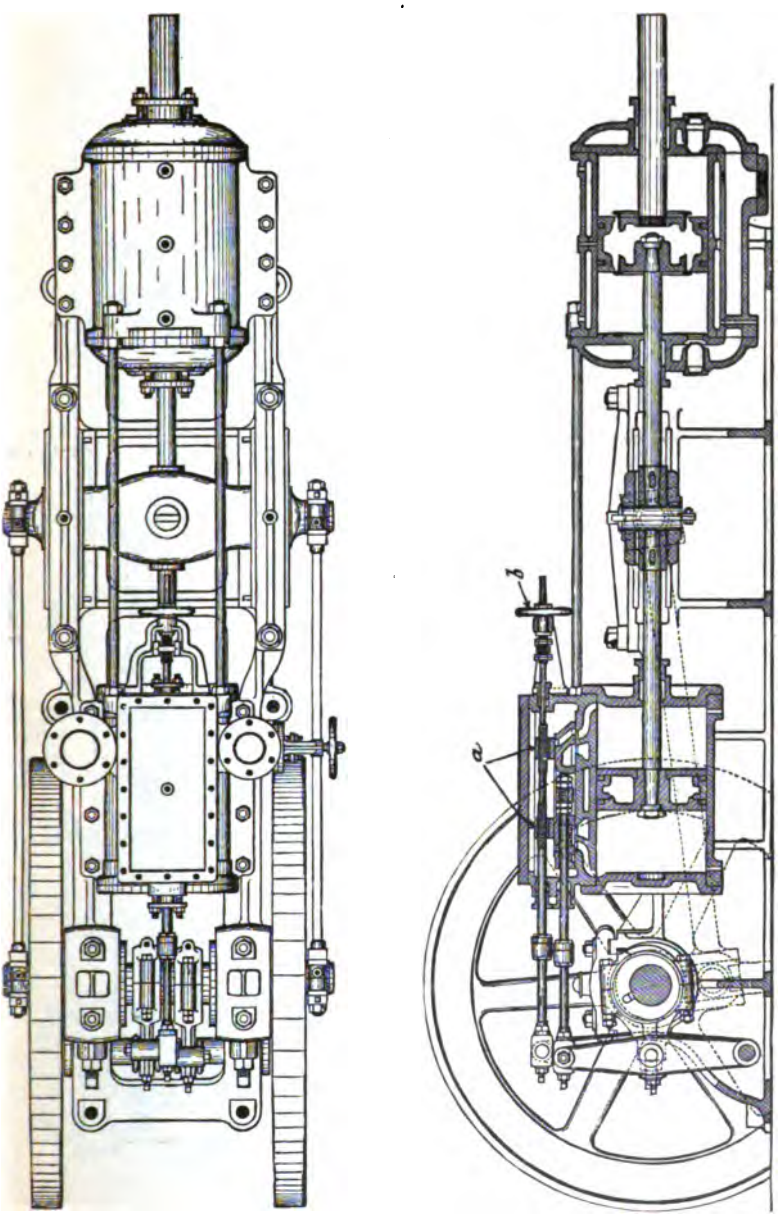


FIG. 1.

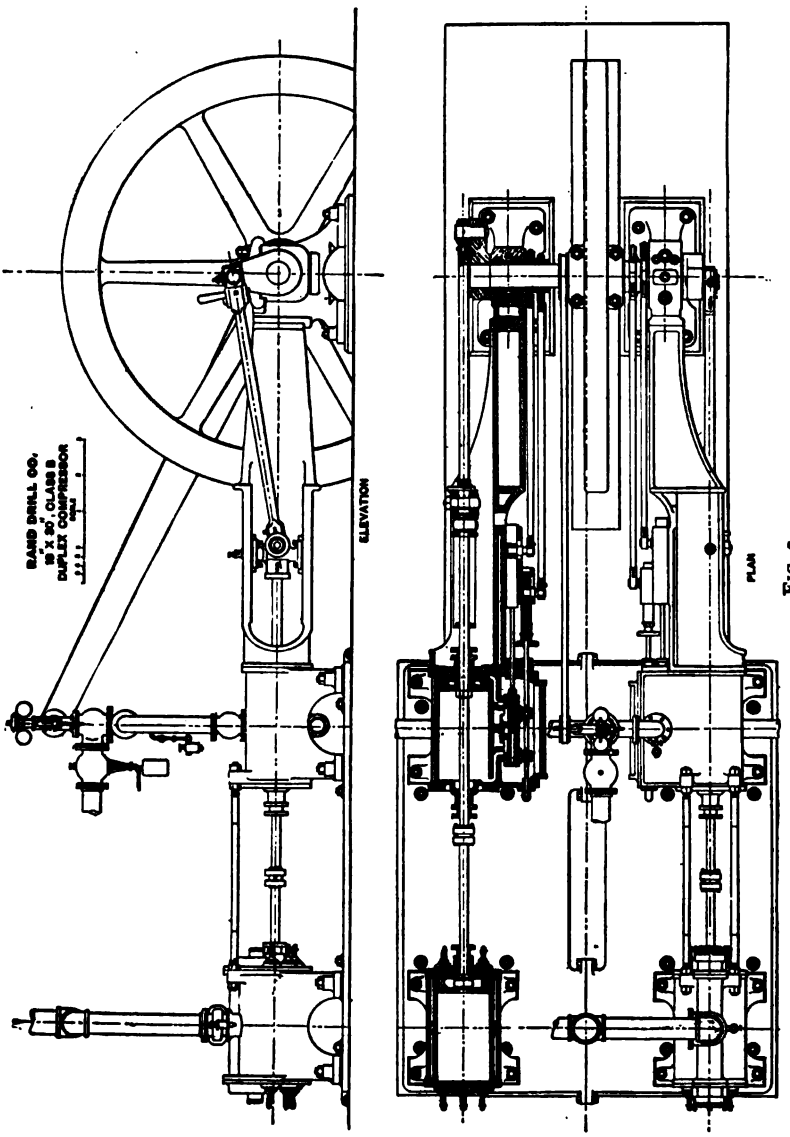


FIG. 2.

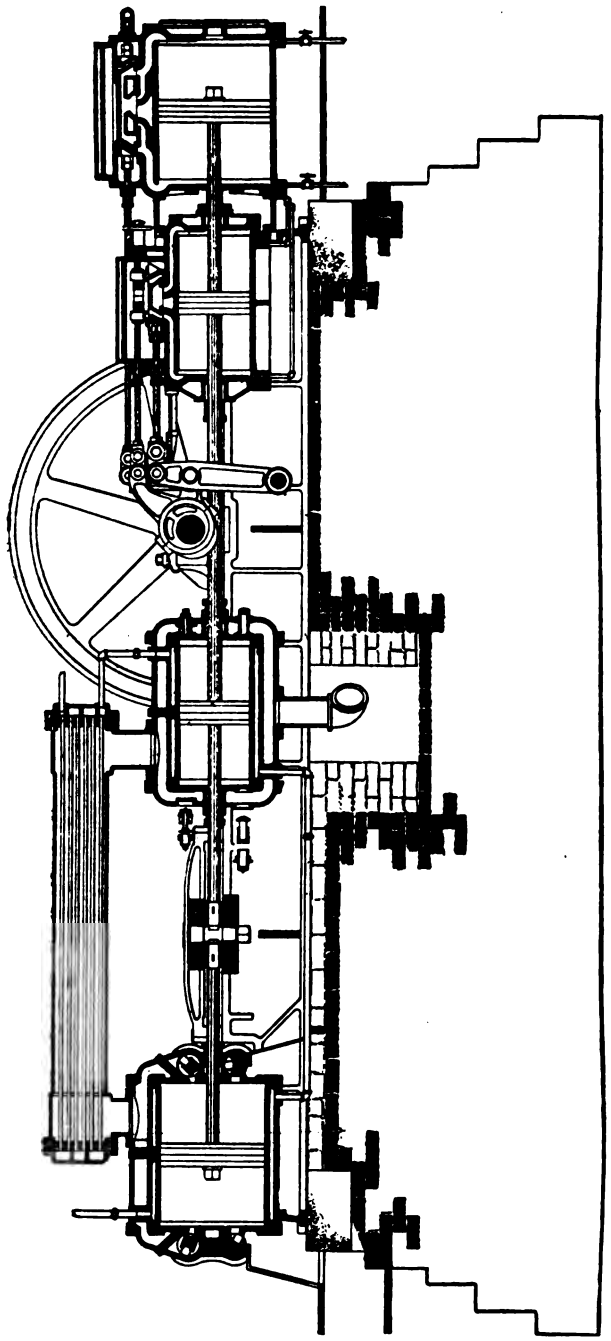


FIG. 3.

E. Compound or stage-compressors, in which the cylinders themselves are compounded. The compression is carried to a certain point in one cylinder and completed at the desired pressure in the other. They may be either of the single or duplex form, with simple or compound steam cylinders. Fig. 3 gives a longitudinal section of a recent type of Norwalk compressor.

The first three classes are those commonly employed for mine service, but the principle of compound air compression is now recognized as applicable for even the moderate pressures required in mining, and the compressors of class E are coming into more general use. The vertical type, class D, is, as a rule, adopted only for very large plants. It may be sometimes an incidental advantage of the vertical form that it occupies less floor space, but it is rarely used for mines. The horizontal engines have a much larger area of base, and the engine frame and foundation are less expensive. They are more accessible, also, for attendance, oiling and repairs. Compressors with compound steam cylinders are becoming widely used, as they make possible a greater degree of economy in the production of compressed air. In at least one make of compressors, compound steam cylinders are used even for the straight-line pattern. (Fig. 3.)

In the first class mentioned, which is a very compact form largely employed for compressors of moderate capacity, the air and steam cylinders are just far enough apart to allow the cross-head to be placed between them. From this cross-head a pair of fly-wheels are driven by connecting rods on each side. The best form of cross-head has a swivel connection with the piston rod to allow for irregularity in alignment, thus avoiding undue friction and unequal wear. The fly-wheels are mounted at each side of the steam cylinder, and are solidly supported by the same frame and bed-plate. By using a pair of fly-wheels for these small compressors, not only are the moving parts better balanced, but each fly wheel may be made smaller and lighter than if there were but one. In the horizontal duplex and compound compressors a single fly-wheel is placed between the cylinders at one end of the frame, and is connected through cranks with the steam cylinder piston rods. This is the form in general use for large plants.

Another form of compressor, not often employed, has one air and one steam cylinder, connected by cranks on the fly-wheel shaft. It possesses the advantage that the full power of the steam

cylinder is exerted at the end of the stroke of the air cylinder—just where it is most needed—but the engine is not so well balanced, occupies about three times the space of a straight-line compressor of the same capacity, and requires a much more expensive foundation.

In the tandem duplex compressor (Fig. 2) it is best to place the steam and air cylinders of each pair far enough apart to prevent the same portion of the piston rod from passing into both stuffing boxes. The reasons for this are: (1) the piston rod is apt to wear differently in the two stuffing boxes, so that it becomes difficult to keep them well packed and tight if the rod passes alternately from one into the other; (2) in this construction the steam and air piston rods may be in separate pieces, coupled together between the cylinders. This is a matter of convenience in making repairs. Whenever the tandem form is used it is essential that the steam and air cylinders shall be accurately and rigidly held in alignment. They are, therefore, connected by tie-rods, and are often set on the same bed plate. In the case of straight line compressors of class A, the cylinders are bolted to a heavy girder frame preventing any possibility of movement.

Occasionally the compressor is driven by an engine which furnishes power also for other purposes. This is done by gearing or belting, or by a crank on a separate shaft. It is generally desirable, however, that the compressor be self-contained and independent of other machinery.

Method of Operation of Steam-driven Compressors. In compressing air steam operates under peculiar conditions, and usually works at a disadvantage. An inspection of the combined air and steam diagram (Fig. 4) will make the matter plain. At the beginning of

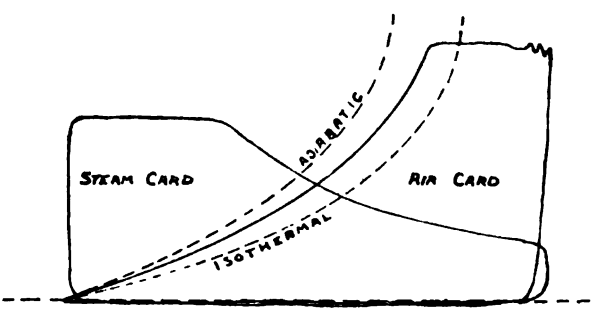


FIG. 4.

the stroke the air in front of the piston is at atmospheric pressure. As the piston advances the air pressure at first increases slowly, while towards the end of the stroke it rises very rapidly. In other words, the resistance in the air cylinder varies from zero at the beginning of the stroke to its maximum near the end. The power developed in the steam cylinder, on the contrary, when working with a cut-off, is in exactly the reverse order. The initial steam pressure is often even lower than the final air pressure, as shown by the diagram. With a steam pressure of 60 lbs., for example, air may be easily compressed to 80 lbs., or more. For compressors, therefore, heavy fly-wheels are required to carry the engine over its center, storing up the surplus steam power in the first part of the stroke, and giving it out at the end. It follows that there is a marked want of smoothness in the running of compressors, which causes severe strains in the moving parts. This is specially noticeable in the simple straight-line type, which, when the air in the receiver is up to gauge pressure, will often be brought almost to a standstill and barely turn over the center. It would appear, then, that only a small ratio of expansion in the steam cylinder could be employed, and in fact some of the older forms of straight-line compressors took steam throughout a large part of the stroke. But this difficulty is met in great measure by the inertia of the fly-wheels and other moving parts. The dimensions of the steam and air cylinders are proportioned for a fixed ratio of expansion within certain limits, and in addition the steam cylinders of many of the straight-line compressors are provided with an adjustable cut-off valve (Fig. 1). This valve *a* moves on the top of the main valve and controls ports in the latter through which steam is admitted to the cylinder ports. It is operated by a separate excentric, and by a hand wheel *b* outside of the end of the valve chest may be easily regulated according to the pressure, which varies with the rate of consumption of air.

A number of arrangements have been devised to equalize the power and resistance, by varying with respect to one another the positions of the air and steam cylinders and their cranks. For example, in the earlier form of Ingersoll, Burleigh and De la Vergne compressors, the cylinders, instead of being parallel to each other, were placed at 90°, with the cranks at 30°. In the old Rand and Waring, of 1876, the cylinders were set at 45°, the steam cylinder being of the oscillating type. The object of these devices was so

to time the movements of the air and steam pistons that the power developed in the steam cylinder should be at its maximum when the air piston was just completing its stroke. But such constructions are difficult to make sufficiently strong and rigid. They require heavy and expensive engine frames and foundations, and the results have not been satisfactory.

Duplex Compressor. Equalization in the work of the two cylinders is attained approximately by the duplex compressor. In this type a considerable ratio of cut-off is used, and the fly wheel needs not be relatively so heavy as for the straight-line. Nevertheless, even here it is customary to use excessively large fly wheels. This form is widely employed for large plants. Besides attaining a greater degree of equalization there are other advantages: (1), the duplex compressor can be run at a very low speed without getting on a center; (2), as each half is complete in itself one side may be disconnected for repairs, or when a smaller capacity is desired. The objections to this form are: (1), the strains on cranks and crank shafts are greater than in regular steam engines working under a uniform load, and therefore require large bearings and a heavy foundation; (2), the loss from friction alone is seldom less than 12 to 15 per cent., while in the straight-line compressor it may be but little more than 5 per cent.*

Size of Air Cylinders. It is customary to build compressors with a short stroke. With a long stroke, and relatively small diameter of cylinder, the piston would travel some distance under a constantly increasing resistance; then after the discharge valves open, it would advance a considerable distance farther under a uniform resistance, while adding nothing to the amount of useful work. In ordinary single-stage compressors the usual ratio of length of stroke to diameter of steam cylinders is $1\frac{1}{8}$ to 1, or 1 $\frac{1}{4}$ to 1, being thus somewhat less than for plain steam engines. The diameter of air cylinder is slightly greater than that of steam cylinder. In some makes of compressor, however, such as the Rand, the ratio of length to diameter is considerably greater than the above, varying from $1\frac{1}{2}$ to $1\frac{2}{3}$ to 1, as in several large plants built for the Calumet and Hecla Mining Co. Under similar conditions the air can be cooled more effectually in a small than a large water-jacketed cylinder, and in this respect several small compressors would produce better results than a single large one. Also, in mine work,

*W. L. Saunders, Compressed Air Production, p. 15.

where the demand upon the air supply is variable, there might be some advantage in a compressor plant composed of several units.

Valve Motion for Steam Cylinders. This is not a vital matter. Compressors of the straight-line pattern, and in general all those of moderate size, are provided with slide valves. Duplex compressors have an easily adjusted cut-off valve, and in the straight-line, as stated above, a special cut-off is introduced, capable of being adjusted by hand while the compressor is in operation. Some makers employ Corliss valve-gear for large compressors of the duplex or compound type. The first cost of this gear is greater, but its advantages in point of economy are well-known. Cornish or poppet valves are used for some of the European compressors.

Compressors Driven by Water Power. Water power may be applied in a variety of ways, but if possible it should be done without the use of gearing. The cranks of the air cylinders may be connected directly with the shaft of an ordinary overshot wheel, the weight of which would supply the place of a fly wheel. Such an arrangement would rarely be necessary, or advisable. With a low head of water a turbine on a horizontal shaft could be used to drive a compressor, or a horizontal turbine through gearing and belting. With a sufficient head, however, a simple bucket impact wheel, like the Pelton or Knight, is much to be preferred, and is frequently used. It is arranged as shown by Fig. 5, the water wheel being mounted upon the crank-shaft; or if the speed be too high

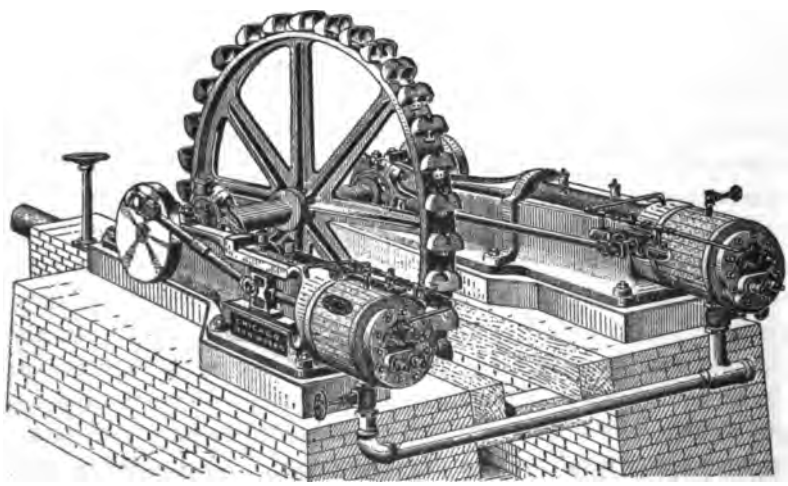


FIG. 5.

it may be geared down. In most cases the wheel may be large enough to render gearing unnecessary. As the power developed by a water wheel is constant, a water driven compressor works more smoothly than one operated by steam, and is specially satisfactory if of the duplex pattern. These impact wheels may be employed with quite small heads of water by introducing multiple nozzles.

Compressors Driven by Electric Power. It is probable that in the future electric motors will be occasionally employed for operating air compressors; that is, when electric plants are installed for general power purposes. An electric plant would hardly be erected for the sole purpose of running a compressor. For obtaining a proper air-piston speed the armature would be geared to the crank shaft. If necessary an electric-driven compressor could be erected underground near the point of application of the power. Most builders have already inserted in their catalogues illustrations and specifications of compressors driven by electric motors.

The Compression of Air.

While there is no question as to the convenience of compressed air as a means of transmitting power, and though it is in such general use for mining and other purposes, yet in the actual work of compressing the air there are considerable losses which to a large extent appear to be unavoidable. Even in the best compressors the useful effect or efficiency, that is, the ratio of the force stored up in the compressed air to the work which has been expended in compressing it, probably never reaches 80 per cent. and often falls below 60 per cent.* To understand the causes of these losses it will be necessary to consider the principles involved in the operation of compressing air. A brief statement only of these principles will be made here.

The relations existing between the volume, pressure and temperature of air during its compression or expansion are expressed by two laws:

1. At a constant temperature the volumes occupied by a given quantity of air (or any perfect gas) are inversely proportional to the pressures. This law is expressed by the equation: $P_1 V_1 = P_2 V_2 = P_3 V_3$, etc., which is a constant quantity. It is given in terms of absolute pressure, that is, above vacuum. (Pressure gauges register pressures above that of the atmosphere, or 14.7

* Frank Richards. Compressed Air, 1896, p. 97.

lbs. per square inch.) Under this law, then, when a quantity of atmospheric air is compressed to 0.147 of its original volume, a pressure of 100 lbs. per square inch is obtained; when compressed to 0.074 of its original volume the pressure becomes 200 lbs., and so on.

2. During the compression of air heat is generated, and when it is allowed to expand again to its original volume this heat is given up. The relation between volume and temperature is expressed by the equation: $PV = P_0V_0(1 + at)$, in which P and V represent the pressure and volume of a given weight of air (or gas) at t°C. above the freezing point, P_0 and V_0 are the pressure and volume of the same quantity of air at the freezing point, and a is the coefficient of expansion of air, which is practically constant and is very nearly $\frac{1}{273}$. Hence, for a rise in temperature of 1°C., the volume of the air increases by $\frac{1}{273}$ of the volume occupied at 0°C., under the same pressure, or $\frac{1}{491}$ per degree Fah. The development of heat reacts upon the air under compression, and increases the pressure which would be due merely to the reduction in volume. By cooling the compressed air to its original temperature the pressure would be reduced to the normal amount, according to the first law. It is evident that this property of air has an important application in the production and use of compressed air. The heat generated during compression and corresponding to different pressures is shown by the following table:

TABLE I.

Pressure in Atmospheres.	Absolute Pressures. Lbs. per Sq. In. above Vacuum.	Volumes in Cubic Feet.	Temperatures, Degrees Fah.	Corresponding Increases of Temperature.
1.00	14.70	1.000	60.0	00.0
1.25	18.37	0.854	94.8	34.8
1.50	22.05	0.750	124.9	64.9
2.00	29.40	0.612	175.8	115.8
3.00	44.10	0.459	255.1	195.1
4.00	58.80	0.374	317.4	257.4
5.00	73.50	0.319	369.4	309.4
6.00	88.20	0.281	414.5	354.5
7.00	102.90	0.252	454.5	394.5
8.00	117.60	0.229	490.6	430.6
10.00	147.00	0.195	554.0	494.0

It follows from the results obtained above that if the temperature of the air be allowed to rise during compression a loss of work ensues.

Methods of Compression. Theoretically, air may be compressed in two ways:

1. The temperature may be kept constant during compression, the heat generated being abstracted by cooling devices as fast as it is developed. In this case the pressure of the air varies according to the first law, and compression takes place isothermally.

2. The temperature may be allowed to rise without check during the period of compression; that is, there is no transference of heat. Here the operation is in accordance with the second law. The rise in temperature increases the pressure which would be due to reduction of volume only. This is called adiabatic compression.

The relations between the two conditions of compression is shown by Fig. 4. By laying off to scale the volumes of air on the horizontal line the corresponding pressures at different points of the stroke are measured on the verticals. The adiabatic curve rises more rapidly than the isothermal, according to the law. Perfect isothermal compression cannot be attained in practice. Even with the best cooling arrangements the compressor would have to run at an extremely slow speed, and be of very large size to approach closely the condition of isothermal compression. On the other hand, if the air compressed adiabatically could be kept hot until used loss of work would be prevented. But neither can this be done. The air is almost always conveyed to considerable distances before it is used, and the loss of heat by radiation from the pipes soon reduces the pressure to that corresponding with the temperature of the surrounding atmosphere. In practice, therefore, neither method of compression is possible. As a matter of fact, a combination or modification of the two is employed, the net result depending upon the degree of perfection of the compressing engine. As shown on the diagram, the actual line of compression must lie somewhere between the adiabatic and isothermal lines. When compressing in a single cylinder to 60 or 80 lbs. pressure, and at a piston speed not exceeding 300 feet per minute, it is probable that about one-half of the total possible cooling is all that may be expected.* The aim is to begin compression at a low initial temperature and to bring the compression line as close

* Frank Richards, Compressed Air, p. 66.

as possible to the isothermal line. It is evident that there is but a narrow margin in which to effect further saving. The air should be cooled as thoroughly as may be during compression and before it leaves the cylinder. Any subsequent cooling must entail additional loss. Some distance must be traversed by the piston, in compressing the air, before there is any considerable rise in temperature, and until the temperature does rise no cooling can be effected. In other words, the abstraction of heat does not begin at the beginning of the stroke. The temperatures of the air taken into the cylinder and of the water used for cooling are likely to be nearly the same, so that all the possible reduction of temperature in the cylinder must take place in a period of time less than that occupied in making the stroke. In fact, most of the cooling is done necessarily in the latter half of the stroke. It should be noted also that soon after the compressor begins running the cylinder itself becomes quite hot and heats the air during intake.

There are two methods of absorbing the heat produced by compression:

1. By injecting cold water into the air cylinder.

2. By cooling the cylinder from without, enveloping it in a cold-water jacket.

Machines of the first class are known as "wet compressors;" those of the second, "dry compressors."

The formula previously cited may be put into the form: $PV^n = P_1 V_1^n =$ constant. The average value of the coefficient n has been found for the different systems of compression. In the case of purely adiabatic compression, with no cooling arrangements, $n = 1.408$; in dry compressors, provided with a water jacket, n is roughly 1.3, while in wet compressors (spray injection) n becomes 1.2. In the poorest forms of compressor the value, $n = 1.4$, is closely approached.* The following diagrams, Figs. 6, 7 and 8, show the relative positions of the several compression lines, the areas between the compression and isothermal lines being shaded in each case. (It should be stated here that these diagrams, with others used in this article, are not actual indicator diagrams. They are intended only approximately to represent the relations between the various lines.)

*Prof. Goodman, Fed. Inst. Min. Engs., Vol. VII., p. 246.

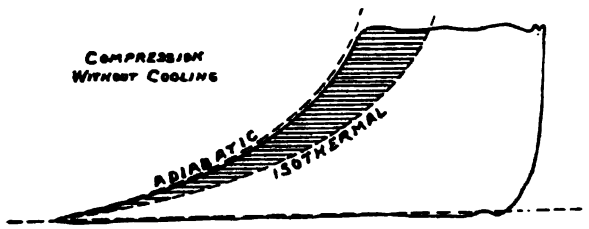


FIG. 6.

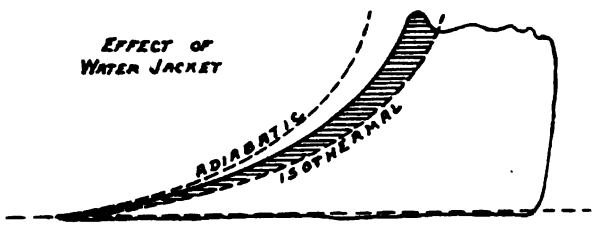


FIG. 7.

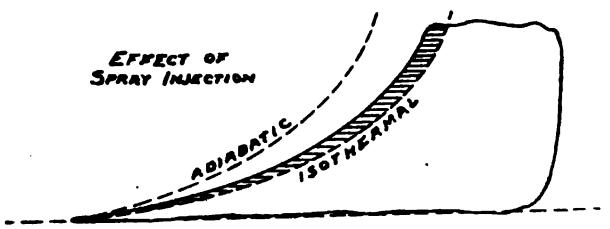


FIG. 8.

WET COMPRESSORS.

Wet compressors are of two kinds:

1. Those in which water is introduced in bulk into the air cylinder and is injected, also, in the form of spray.

2. Those in which water is injected in the form of fine spray or jets only.

Compressors of the first type have been much used in Europe, but are now nearly superseded by later designs. One of the earlier forms, the Humboldt, will serve as as an example (Fig. 9). The water constitutes a piston for compressing the air, an ordinary plunger, like that of a pump, moving in a horizontal cylinder filled with water. At each end of the cylinder, and connected with it by an easy curve, is a vertical air chamber. The upper ends of

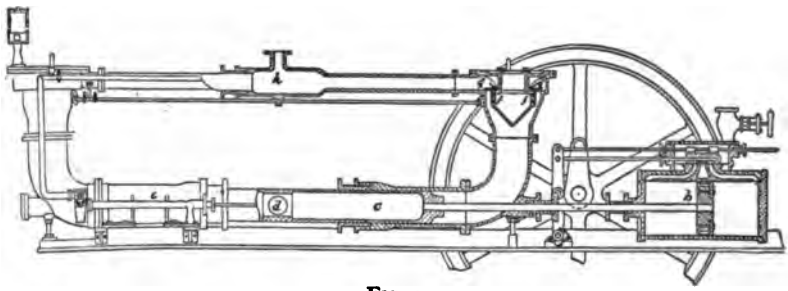


FIG. 9.

these chambers are provided with the necessary air inlet and discharge valves. As the piston moves the air is alternately drawn into one air chamber, and compressed in the other, by the rise and fall of the water level. At the end of each stroke the air compressed by the rising column of water passes through the discharge valve into the receiver. As the air comes into contact with the mass of water a partial cooling is effected, and to prevent the water itself from becoming heated a constant circulation must be maintained. A further cooling is brought about by the injection of sprays into the cylinder and vertical air chambers. This type of compressor is simple, and if the sprays be copious the air is quite effectually cooled, but it is generally limited to rather slow speeds (only 100 to 150 feet piston speed per minute, or less, for some forms), on account of the inertia of the body of water.* This is about $\frac{1}{8}$ to $\frac{2}{5}$ of the piston speed of modern compressors, and it follows that such engines are large and bulky for a given output of air. It is claimed, however, that a more recent form of Humboldt wet compressor, made at Kalk, near Cologne, Germany, can be run successfully at speeds of from 300 to 360 feet per minute, the temperature of the air at discharge being kept at 77° to 80° Fah. (Fig. 10).† This is certainly good work. The machines are made of large size, and the vertical air chambers join the cylinder with a curve of long radius to ease the movements of the mass of water.

A serious difficulty with wet compressors of this class is that the water tends soon to become hot, and an efficient circulation of cold water is not easy to maintain. Only a small amount of fresh water can be injected at each stroke, and if no sprays be used the cooling is exceedingly imperfect.

* *Colliery Engineer*, Aug., 1894, p. 6.

†P. R. Björling, *Colliery Guardian*, Oct. 2, 1896, pp. 629–630.

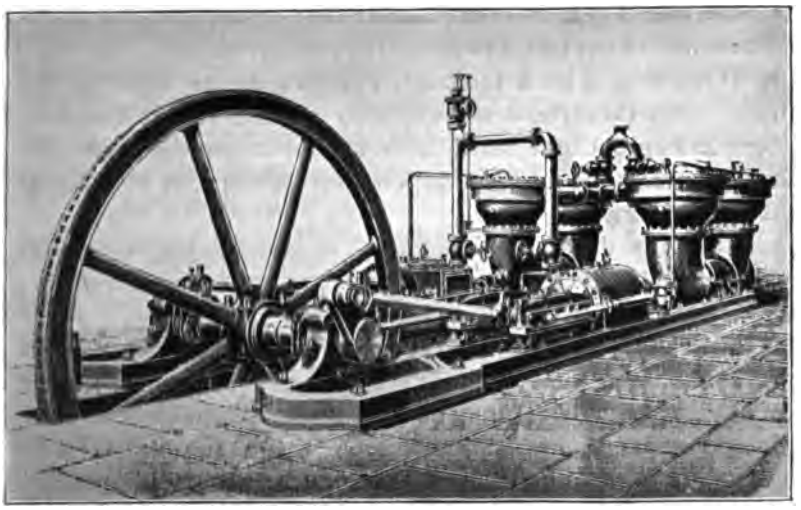


FIG. 10.

Compressors of the second class, in which water is used only in the form of jets or spray, constitute an improvement upon the older design, in being much less cumbrous and permitting a higher working speed. Though still frequently used they have given way in great measure to dry compressors, at least in American practice. The air cylinder does not differ materially in general structure from that of the dry compressor. A small water pipe is tapped into each cylinder head, and fine spray is injected into the air in front of the piston while compression is taking place. A dry compressor may be converted into a wet compressor merely by providing the cylinder with these water jets. The injected water collects in the cylinder until enough is present to fill the clearance space at the end of the stroke. Then any additional amount of water is forced out at each stroke with the compressed air through the discharge valves into the air receiver. From the receiver it is drained away at the bottom from time to time. The water used for injection should be as pure and cold as possible. Gritty water must never be employed, as it would injure the cylinder, piston and valves.

A proper injection apparatus should fulfil three conditions: *

* W. L. Saunders, *Eng. and Mining Jour.*, Oct. 30, 1888, p. 310. See also *Colliery Guardian*, Aug. 28, 1896, p. 396.

1. The injection must commence at the beginning of the stroke and continue to the end, against the advancing piston.

2. There should be a thorough diffusion of the water in the form of spray throughout the cylinder. By mere surface contact water takes up but little heat. Even a single strong jet is quite effectual, however, because on striking the piston it is thoroughly broken into spray.

3. A definite volume of water must be injected, the volume increasing with the pressure under which the compressor is working, that is, with the quantity of heat generated.

If the quantity of water used be insufficient to abstract the heat a large amount of moisture will be taken up by the warm air and carried into the receiver and piping. The heat units developed by compression having been calculated, the quantities of water required for different pressures are shown in the following table.

The average temperature of injection water may be taken as say 68° Fah., and is considered as having accomplished its work if it leaves the cylinder at 104° Fah., these temperatures corresponding respectively to 20° and 40° C.*

TABLE II.

Pressures.		Heat units developed by compression in 1 lb. of free air.	Pounds of water to be injected at 68° F. to keep temperature at 104° F.	
Above vacuum. Atmospheres.	Gauge pressure. Pounds.		Per. lb. of free air.	Per. cu. ft. of free air.
2	14.7	3.702	0.734	0.056
3	29.4	5.867	1.164	0.089
4	44.1	7.406	1.469	0.113
5	58.8	8.598	1.701	0.131
6	73.5	9.570	1.891	0.145
7	88.2	10.398	2.063	0.158
8	102.9	11.109	2.204	0.167
9	117.6	11.740	2.329	0.179
10	132.3	12.301	2.440	0.188

DRY COMPRESSORS.

In the dry system of compression no water enters the air cylinder except that which is carried as moisture in the air itself. All

* The table is modified from that given by Zahner, "Transmission of Power by Compressed Air," p. 110, English units being substituted for French.

the cooling during compression is effected by a water envelope, or "jacket," surrounding the cylinder, and in which cold water is kept constantly circulating.

Fig. 11 shows the longitudinal section of one of the latest forms of jacketed air cylinder—the Ingersoll-Sergeant. The complete compressor is shown in plan and section in Fig. 1. The cylinder

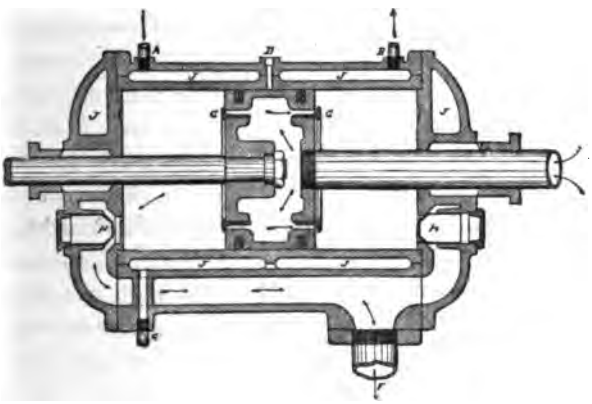


FIG. 11.

is enclosed in an outer shell, leaving an annular space, J, to be occupied by the water. Besides the annular jacket nearly one-half the area of each end of the cylinder is also covered by a water jacket. The remainder of the end areas is occupied by valves, as shown. The circulation of water is effected by pipes connecting with the openings A and B, for inlet and discharge. To cause a proper circulation the space inclosed by the jacket is divided into two parts. The cold water enters at A, and after circulating through the annular space JJ, around the forward end of the cylinder, passes through an opening in the bottom of the jacket to the rear end, from which the warm water is finally discharged at B. The smaller jackets on the cylinder heads are also connected with the system of circulation. C is a drain through which the jacket is blown out occasionally to clear it of sediment. In the Clayton compressor the jacket is divided by partitions so that the cold water entering at the top passes first around about one-quarter of the length of the cylinder nearest each end. The water then circulates around the middle portion of the cylinder and discharges at the top. In this arrangement the fact is recognized

that at the end of the stroke, where the air pressure is highest, the greatest amount of heat is generated. A tank at some elevation above the compressor is usually provided for furnishing the circulation water, or a small pump may be employed.

Naturally, a partial cooling only can be effected by jacketing the air cylinder. Heat is generated faster than it can be abstracted, and only a portion of the volume of air passing through the cylinder comes into direct contact with the cooling surfaces. It is important, therefore, that as much as possible of the total cylinder surface be covered by the jacket, and that the piston speed be moderate. But, as the air is comparatively free from moisture, some heating is not so objectionable as it would be in a wet compressor. As a matter of fact, the cylinder, discharge pipe and even the receiver, are usually quite hot when the compressor is running at full speed. In some compressors the inner shell of the air cylinder is made of hard brass, which by its high conductivity assists in carrying off heat. With the same end in view the cylinder shell should be as thin as is consistent with safety. To furnish a larger cooling surface one style of Rand compressor has a hollow back piston rod and a hollow piston, through which water is circulated. This back piston rod works telescopically in a stationary tube connected with the water supply.

Piston Clearance in the Air Cylinder. In every engine, whether steam engine or compressor, the amount of clearance at the end of the stroke, between the piston and cylinder head, is a matter of some importance. It has a special bearing in the case of a compressor for the following reason. At the end of the stroke the compressed air in front of the piston begins to pass through the discharge valve when its tension reaches that of the air in the pipe leading to the receiver. But the warm compressed air filling this space can be never wholly discharged from the cylinder of a dry compressor.

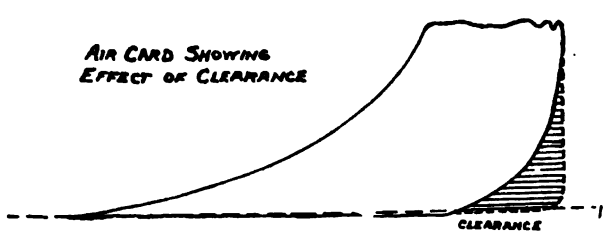


FIG. 12.

On the back stroke it expands again and partly fills the cylinder behind the piston. No air can enter through the inlet valves until the pressure inside the cylinder falls below atmospheric pressure. It is never possible, therefore, to take a full cylinder of fresh air even under the best conditions, and the clearance space must be made as small as possible. The diagram, Fig. 12, shows the effect of clearance. Although it causes a loss in the capacity of the compressor it does not involve an actual loss of power. Fig. 13 indicates the method of reducing the clearance for ordinary pistons, by casting a recess in the cylinder head to receive the projecting piston nut at the end of the stroke. The loss of volumetric efficiency due to clearances of course increases with the air pressure, and in some compressors the piston is run exceedingly close to the cylinder head. When this is the case the compressor must have careful attention, so that when the connecting rod is shortened by tightening up the brasses, as they wear, the piston will not be in danger of striking the cylinder head.

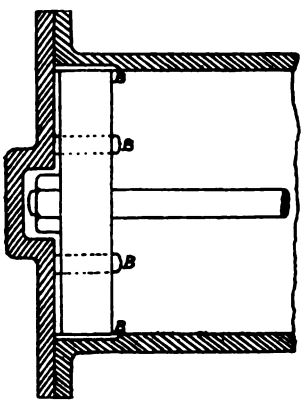


FIG. 13.

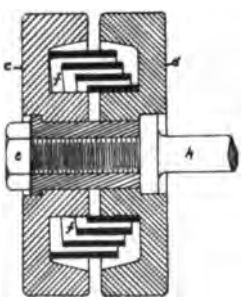


FIG. 14.

The Johnson compressor, made in England, has an ingeniously contrived piston to meet the difficulty just mentioned, (Fig. 14). It is composed of two discs, *c* and *d*, mounted upon a bronze sleeve screwed on the piston rod, *h*, and held in place by collar and locknut. The two discs forming the piston are so cast as to leave between them a recess in which is placed a heavy helical spring, *f*. This spring is compressed sufficiently between the piston discs to prevent it from being further compressed under the maximum

working air pressure, but the clearance at the ends of the stroke is extremely small, and should the piston strike the cylinder head the spring gives slightly and an injurious shock is avoided.*

A number of other devices have been adopted for overcoming the disadvantages of piston clearance. Two examples may be given:

1. Longitudinal bye-pass grooves (*BB*), are cast in the inner surface of the cylinder near the ends, Fig. 13, so that when the piston reaches the end of its stroke a part of these grooves is uncovered, and the compressed air in the clearance space passes to the other side of the piston.

2. In slide-valve compressors the valve may be provided with a so-called "trick-passage." At the end of the stroke this passage is brought into connection with two small ports entering the extreme ends of the cylinder. Through these passages the high-pressure air in the clearance space is released into the other end of the cylinder.

By such methods the released air becomes of direct benefit instead of being a disadvantage. But there is a decided objection to the employment of such devices if all the confined air be allowed to pass over, because the heavy pressure on the piston at the end of the stroke is suddenly removed, and there is a shock to the moving parts. In the most recent forms of compressor made in the United States the clearance space is very small, but the air confined in it is not released. It furnishes some compensation in helping to overcome the inertia of the moving parts at the beginning of the return stroke.

Dry versus Wet Compressors.

Up to about 1885 there seemed to be little doubt among mechanical engineers that the wet compressors were upon the whole superior to the dry, because by bringing the air into direct contact with water the heat is most effectually absorbed. This view is correct so far as heat loss alone is concerned. Without cooling the percentage of work converted into heat during compression, and therefore lost, is as follows:

* Björling, *Colliery Guardian*, Aug. 7, 1896, p. 272.

Compression to		2	atmospheres,	9.2%	loss.
"	"	3	"	15.0%	"
"	"	4	"	19.6%	"
"	"	5	"	21.3%	"
"	"	6	"	24.0%	"
"	"	7	"	26.0%	"
"	"	8	"	27.4%	"

In the best dry compressors, working at a pressure of 5 atmospheres, the heat loss is reduced about one-half, or from 21.3 per cent. to 11 per cent. By spray injection this loss has been cut down in good American practice to as little as 3.6 per cent., and in some of the slow-running European wet compressors to 1.6 per cent.* But the question of heat loss is not the only consideration. Low first cast and simplicity of construction are often more advantageous than the attainment of a high degree of isothermal compression. Latterly the wet systems have lost ground in the United States, and in Europe, also, dry compression has grown in favor, at least for mining plants and others of moderate size. The matter may be considered from two standpoints, as regards:

1. The effect of injected water upon the compressed air and the machine using it.

2. The effect of the water upon the working of the compressor. In addition, it is necessary to take account of the relative efficiencies of the two types, but this will be deferred until later.

First, there is no question, as has been pointed out, that by using large slow-speed engines, and an abundance of injection water, the air is well cooled, though at a higher first cost for plant. Wet compression gives a good indicator card, also. It is shown by the following table that in compressing moist air less work is expended than for dry air. This is due to the fact that the specific heat of watery vapor is about twice that of dry air; therefore in the presence of moisture more heat is required to raise the temperature of the air in the compressing cylinder, and the loss of work is reduced.†

* W. R. Saunders, Compressed Air Production, p. 24.

† Goodman, Trans. Fed. Inst. M. E., Vol. VII., p. 245.

TABLE III.*

Absolute Pressure. Atmospheres.	Gauge Pressure. Pounds.	Foot Pounds of Work Required to Compress One Pound of Air.	
		Dry Compression.	With Sufficient Moisture.
1	0		
2	14 7	23,500	22,500
3	29.4	37,000	35,000
4	44.1	48,500	45,000
5	58.8	58,500	52,500
6	73.5	67,000	60,000
7	88.2	75,000	66,000

Theoretically, a corresponding economy takes place also when the air is expanded again in the machine using it.

Notwithstanding these advantages several serious objections became apparent in the use of the wet system of compression. Other things being equal the amount of heat given up is proportional to the difference of temperature between the air taken into the cylinder and the injected water, and to the time of contact between the air and water. Under ordinary circumstances this difference of temperature is zero at the beginning of the stroke, reaching its maximum at the end. It follows: (1) that to attain a fair approach to isothermal compression the piston speed must be very slow; (2) that during the first part of the stroke but little heat is removed, and it is only when compression is complete, and the air begins to pass through the discharge valves, that the cooling effect is at its maximum. At ordinary piston speeds, therefore, a large proportion of the total heat must be given up after the discharge valves have opened; in other words, after compression is completed.† The warmth of the air at discharge augments its moisture carrying capacity, and though it is intended that the separation of the water shall be as complete as possible in the air receiver, still it must of necessity be imperfect in a receiver of any reasonable size. Much moisture passes into the air mains and deposits as the air cools down in long lines of piping. In cold weather it may freeze so as to reduce the effective diameter of the pipe. The moisture remaining in the air has a further ill effect

* Abstract from a table by Mr. Norman Selfe, Trans. Eng. Assn. of New South Wales.

† A. C. Elliott, Trans. South Wales Inst. M. E., Vol. 17, p. 170.

when it is used. At the instant of exhaust by the drill, or other air engine, the intense cold produced by expansion causes the formation of troublesome accumulations of ice in the exhaust passages.

As to the dry compressor it must be admitted that as air is a poor conductor of heat it has little opportunity to give up its heat of compression between the strokes of the piston. Besides this, the piston, as it advances, rapidly covers the jacket-cooled surface of the cylinder. However, although atmospheric air as taken into the compressor always contains moisture, which will make its appearance as frost at the exhaust of the air machine, still there is not enough of it to cause serious trouble. The delivery of warm air by a dry compressor is far less objectionable than warm air from a wet compressor. More remains to be said upon this subject under "Compound Compression of Air."

Second, as to the effect of injected water upon the working of the compressor. Under the best of circumstances water in the air cylinder is objectionable because it makes lubrication difficult, causes rust, and increases the wear of piston and cylinder. No satisfactory method has ever been devised for lubricating the inner surface of wet compressor cylinders. This is one of the chief difficulties with wet compressors, and becomes most serious when the water is impure or gritty. It must, of course, contain no trace of acid, such as is often present in mine water. Water that is comparatively harmless for the use of jackets might be decidedly injurious to the finished surfaces of working parts.

It is urged on behalf of wet compression that the piston clearance space is filled with water, and the capacity of the compressor is therefore increased. While this is true, yet, as water is incompressible, and as a part of it must be forced out through the discharge valves at each stroke, the wet compressor is compelled to work in a measure like a water pump. Furthermore, closer attendance is required in regulating the water supply when the compressor is standing still or running very slowly. The drip cock at the bottom of the receiver must also be watched more closely to prevent flooding, and there is the disadvantage of having an injection pump to care for and regulate.

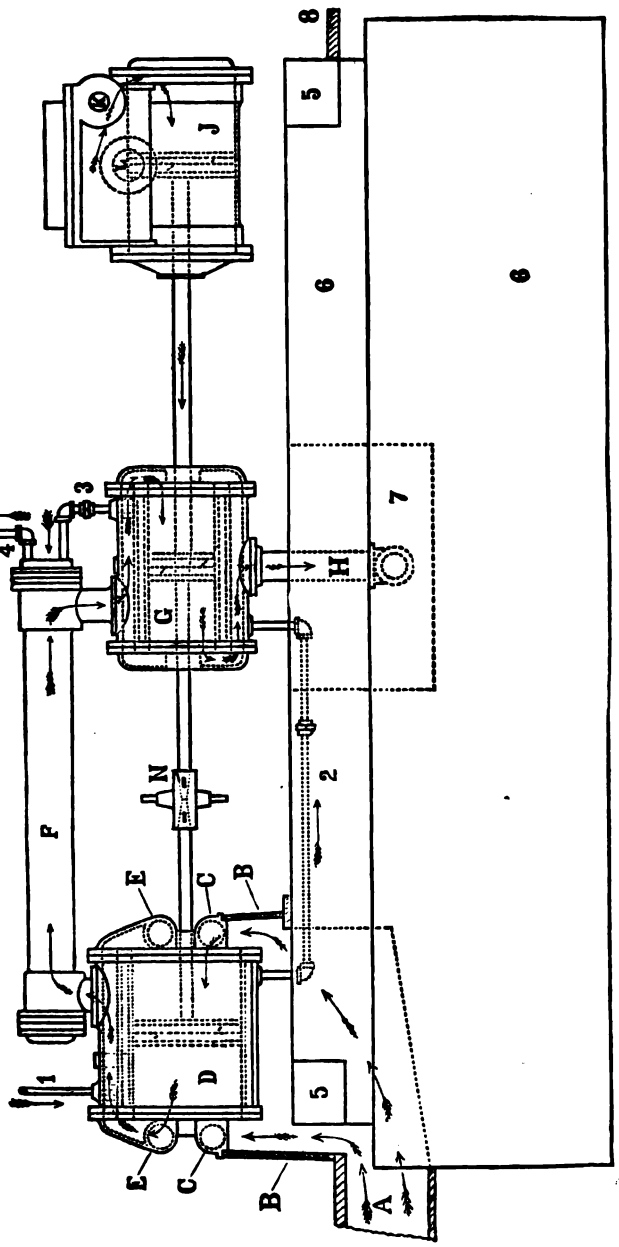
Compound or Two-Stage Air Compressors.

The operation of a compound compressor is the reverse of that of a compound steam engine. Air at atmospheric pressure is

taken into the large, or low-pressure, cylinder; is there compressed to a certain point, and is then forced into the smaller, or high-pressure cylinder, where it is brought up to the required tension. Manifestly, the sizeof the low-pressure cylinder determines the capacity of the compressor.

Formerly it was customary to employ compound cylinders only when high pressures were required, such as for pneumatic locomotives, riveting machines, presses, compression of gases, pneumatic guns, etc. The efficiency of compound compression increases with the air pressure produced, and the higher the pressure the greater becomes the necessity for compounding the cylinders. For extremely high-pressures, triple and even quadruple cylinders have been employed. It is recognized now that compound, or stage, compression may be advantageously applied for even the ordinary pressures of 70 or 80 lbs., commonly used in mining operations. By it some of the difficulty due to the development of heat during compression is overcome. In an ordinary compressor all the heat is generated rapidly in a single cylinder, and can be only partially abstracted by cooling devices. Under the best conditions the compressed air as discharged from the cylinder carries a considerable degree of heat, and loss of pressure due to subsequent cooling must always take place. In a compound compressor, on the other hand, the cooling is more perfect. The total heat generated is divided between the two cylinders, and when both are water-jacketed, as they should be, a much larger cooling surface is presented. A further cooling is effected by an "intercooler," which forms an important adjunct of a compound compressor. Fig. 15 is a diagram showing the position and form of the intercooler as used on the Norwalk compressor, and upon it is indicated the course of the air from one cylinder to the other. Fig. 3 gives a vertical longitudinal section of the latest design of the same compressor, with compound-steam as well as air cylinders.

The intercooler is an intermediate chamber through which the partially compressed air from the intake, or low-pressure, cylinder passes on its way to the high-pressure cylinder. For ordinary purposes the intercooler is practically a section of large piping, containing a number of parallel thin copper tubes, through which cold water is circulated. In passing between the tubes, which have a large total area, the air may be cooled nearly to normal atmospheric temperature before it enters the high-pressure cylin-



Arrows on the water pipes show the direction of water circulation. When pistons move as indicated by the arrow on the piston rod, the steam and air circulate in direction shown by arrows in the cylinders

A—Inlet Conduit for Cold Air.
B—Removable Hoods of Wood.
C—Inlet Valve.
D—Intake Cylinder.
E—Discharge Valve.
F—Intercooler.
G—Compressing Cylinder.
H—Discharge Air Pipe.
J—Steam Cylinder.
K—Steam Pipe.
L—Exhaust Steam Pipe.
N—Swivel Connection for Crosshead.
1—Cold Water Pipe to Cooling Jacket.
2 & 3—Water Pipe.
4—Water Overflow or Discharge.
5—Stone on end of Foundation.
6—Foundation.
7—Space to get at underside of Cylinder
8—Floor Line.

FIG. 15.

der. The intercooler of the Schram (English) compound compressor is a vertical chamber, filled with small tubing. The water enters at the bottom, passes up through one-half of the tubes and down through the other half, the lower water-head being divided accordingly. The air from the low-pressure cylinder enters at the top of the intercooler.

Both cylinders should be water-jacketed as in ordinary single-stage compressors. The additional heat developed by the fina compression in the high-pressure cylinder is partially abstracted by its water-jacket. It is clear that the temperature of the compressed air delivered by a compound compressor must be somewhat lower than that from the simple compressor, because, aside from the effect of the intercooler, the smaller amount of heat developed in each cylinder is more effectually dealt with by their respective water-jackets. This is indicated by the diagram, Fig. 16.

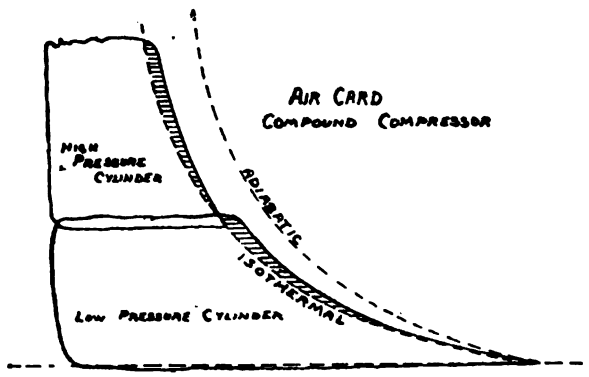


FIG. 16.

That compound compression under favorable conditions gives a high degree of efficiency is shown by the results obtained from the large compressors of the Paris Pneumatic Supply Co. Spray injection is applied to both cylinders, and also to a plain intermediate receiver of large capacity. The air is compressed to 88 lbs., and the indicator diagrams of the air cylinders exceed in area the true isothermal diagram by only 12%.*

The useful effect of the intercooler should not be exaggerated. It must be remembered that real economy in air compression is obtained only by cooling *during* compression in the cylinders

* Proceedings Inst. C. E. London, Vol. CV., p. 180.

themselves. The value of the intercooler lies in the fact that cooler air is delivered to the high pressure cylinder, thus making possible a somewhat lower final temperature.* The higher the pressure the more useful does the intercooler become. It is important that the copper tubes in the intercooler be kept clean. As the oil carried over by the air tends to deposit on the tubes they should be so arranged as to be easily removed for cleaning. For large plants intermediate cooling receivers are sometimes made of much greater volume than that shown on the cuts.

Two other advantages of the compound compressor are to be noted:

1. It has practically but one clearance space—that in the low-pressure cylinder—and as the air here is at a comparatively low tension—the resulting reduction in net cylinder capacity is not large.

2. The total variation in resistance throughout the stroke, and the maximum resistance at the end of the stroke, are much less than in single-stage compression. Take, for example, two compressors, one having a single air cylinder 20 inches diameter, the other having compound cylinders, of which the low-pressure cylinder is also 20 inches diameter, and both compressing air to 80 lbs. per square inch. In the low-pressure cylinder of the compound compressor the air is compressed to say 25 lbs., producing a total pressure on the piston at the end of the stroke of 7,854 lbs. The high-pressure cylinder, completing the pressure to 80 lbs., has a diameter of 13½ inches, and the corresponding resistance at the end of stroke is 11,451 lbs. But the 25-lb. pressure of the low-pressure cylinder acts upon the *back* of the high-pressure piston, It amounts to 3,578 lbs., which, being subtracted from 11,451 lbs., leaves 7,873 lbs., as the net maximum resistance in the high-pressure cylinder. The total resistance in both cylinders varies, therefore, between 3,578 lbs., at the beginning of the stroke, to 15,727 lbs., at the end. In the single 20-inch cylinder, on the other hand, the variation is from zero to 25,133 lbs. It follows that, as the strains in all the parts are diminished and there is less irregularity in working in the compound compressor, the engine frame, etc., need not be so heavy as for the single-cylinder compressor.

Compound compressors are made both single-and double-acting. For high pressures there is some advantage in single-acting

* In this connection see "Compressed Air," by Frank Richards, chaps. 8 and 9.

two-stage compressors, as more time is given for cooling the air; but the frictional loss is increased, and it is evident also that throughout an entire revolution there is much greater variation in resistance and a consequent lack of smoothness in running. For the ordinary pressures used in mining double-acting compressors are preferable.

The Ingersoll-Sergeant Drill Co. have recently introduced a very compact form of compound compressor. It is of small size (about 25 H. P.), self-contained, and requires very little in the way of foundation. The peculiarity of its construction consists mainly in the arrangement of the cylinders. In the middle are the tandem air cylinders, whose crank is placed between a pair of fly wheels. On each side of the high-pressure air cylinder, and rigidly bolted to the same engine frame, are the steam cylinders, which may be either simple or compound duplex. The cranks of the steam cylinders are, therefore, outside of the fly wheels.*

(*To be continued.*)

PUZZOLANA AND ITS PRACTICAL USE.

BY JOSEF ZERVAS.

Puzzolana is one of the oldest materials used for making mortar, especially hydraulic mortars. It entered largely into the construction of all the important works built by the Romans from the earliest period of their existence as a nation, and is fully and quaintly described by Vitruvius in the fourth chapter of the second book of his work. The remarkable hardness which the Roman mortars attained with age was largely due to the employment of Puzzolana mixed with fat lime and sand. Formerly Puzzolana was found principally in the neighborhood of Naples, and especially at Puzzuoli, hence the name. At the present time similar material is known sometimes under different local nomenclature like that from the river Rhine (Germany), where the hard, stone-like variety is called "tuffstone," the powdered "Trass;" from the Azores islands, where the name of Puzzolana has been adopted, but a red variety is called "Tetin;" from Schemnitz (Hungary); from Au-

* *Engineering and Mining Jour.*, Dec. 12, 1896, p. 561.

vergne (France); from Teneriffa, where it is called "Tosca;" etc. The "Santorin-earth" from the Greek island "Santorin" is also to be ranged with the Puzzolanas.

Puzzolana is of volcanic origin, and in its natural state appears as a deposit of powdered and coarse ashes, and often contains pieces of pumice stone.

Where such ashes were mixed with or deposited in water, the mud thus produced hardened to a certain degree while drying. The tuffstone of the river Rhine is a good example of this. In case the yet moist Puzzolana were covered by a hot lava stream which allowed evaporation of the water after an energetic action of oxidation on the hydrous oxide of iron, which, at the same time, lost part of its water, the color of the Puzzolana changed to red, and often the part in contact with the hot lava became as hard as a brick. An example of this is the "Tetin" of the Arores.

The latest Tertiary period produced the best Puzzolana now used in mortar. H. von Dechen* and L. Dressel† accord that the trachytic-leucitic and pumice stone tuffs of the Laacher See (river Rhine) originated at the end of the Tertiary period and the beginning of the Loess deposits.

It may be observed that but trachytic and pumice stone tuff is fit for mortar purposes, while the leucitic tuff yielded almost no useful result. However, leucittuff yields an excellent building stone, especially for ornamental work, and has been used extensively in churches and other monumental buildings in Germany.

The origin of the leucittuff is somewhat different from that of the trachytic and pumice stone tuff, as it is considered not to be ejected, but to flow out from the volcano in a mud stream—Moja.

The Italian Puzzolana is mostly obtained by digging it from open pits of slight depth; however, very large deposits are also found. That of Trentaremi furnishing a light brown yellowish Puzzolana, is more than 600 feet deep, of great extent and situated immediately on the sea. The average production in 1885 amounted to 100 tons per day. The deposits of the dark gray Puzzolana of Santa Maria della Bruna near Torre Anunciata, on the slope of Mount Vesuvius, is estimated at 2,000,000 tons, and can furnish 150 to 300 tons per day. Comparatively little care is

* Geognostischer Führer zum Laacher See und seinen vulkanischen Umgebungen. Bonn, 1864.

† Geognostisch-geologische Skizze der Laacher Vulkangegend. Münster, 1871.

exercised in the selection of the localities from which Puzzolana is taken, a matter of great importance, although it is evident that a natural material of this character, the product of successive volcanic eruptions, must vary greatly in its chemical and physical constituents. Besides neglecting the necessary preliminary tests and explorations, the Italian manufacturers have been very careless in the grinding and screening of the Puzzolana after it has been excavated, and, as a necessary consequence, the manufactured article varies greatly in quality. The Italian Puzzolana, beside being poorly manufactured, is inferior to other Puzzolanas, such as are found on the Rhine (Germany) and in the Azores, in the character of the material itself. This want of uniformity in the Italian Puzzolana has made the French engineers employ less of it in their marine constructions than they did formerly. Therefore, it is not surprising that Italian Puzzolana from Castelamare, imported into the United States by a firm from Boston, Mass., in 1886, proved an entire failure.

The Dutch engineers, on the contrary, whose very existence depend on the stability of their hydraulic works, employ "Trass" (which is closely allied to the Italian Puzzolana, but is selected and manufactured with much greater care) in all their important places, on account of its cheapness and strength.

Puzzolana of the Azores is a yellowish to brownish, sometimes grayish, earth-like powder, which is often fine enough to use as a mortar without grinding or screening. "Trass," on the contrary, is a pulverized stone called tuffstone, which is about as hard as brick, varies in color from bluish-gray to yellow, and is found as a porous mass, interspersed with pumice stone. The harder the tuffstone the better its quality. The tuffstone, especially in the valley of Brohl on the river Rhine, is generally, sometimes up to 100 feet, covered by powdered Puzzolana containing much pumice stone, which is called "mountain Trass," and is by far inferior to tuffstone for mortar purposes.

Both Puzzolana and Trass are the products of the eruptions of former volcanoes and, although quite different in their physical appearance, they give nearly the same chemical analysis. They also give the best results for hydraulic mortars when the materials have been found at the original place of deposit, near the volcano from which they were first ejected.

General Q. A. Gillmore, in his standard treatise on limes, hy-

draulic cements and mortars, makes the following reference to Trass and Puzzolana: "Trass or Teras.—In the valley of the Rhine, between Mayence and Cologne and in various localities in Holland, a substance of volcanic origin is found called Trass or Teras, which has been extensively employed throughout that region, particularly by the Dutch engineers, for the production of hydraulic mortar. It is derived from immense pits or quarries occupying the sites of extinct volcanoes, and enjoys in every particular the distinguishing properties of Italian Puzzolana, closely resembling it in its composition and in the details of its manipulation, requiring to be pulverized and combined with rich lime in order to render it fit for use, and to develop any of its hydraulic properties." The above description of the Trass and Puzzolana is substantially correct, except that General Gillmore should have said "between Coblentz and Cologne," instead of Mayence and Cologne, and should have omitted the words "in various localities in Holland," as no Trass is found in Holland unless it is imported from the above-named locality in Germany.

The analysis on next page shows how much Trass and Puzzolana resemble each other, and also that the chief ingredients are silica, alumina and iron oxide.

The proper amount of lime that is necessary to use with Puzzolana and Trass mortars varies with the character of the work and the quality of the Puzzolana and lime. Mortar composed by volume of one part each of Puzzolana, powdered lime, and sand, probably gives better results than any other combination of these materials, although larger proportions of lime and sand may be used where great strength is not required.

At the great harbor improvements at Kiel (Holstein) the following mixture was adopted:

3 volumes of Trass.
2 volumes of fat lime paste.
7 volumes of sand.

In Holland the following composition is the standard for the hydraulic works:

	Trass.	Shell Lime Paste.	Sand.	Stones.
Strong Trass mortar	1 vol.	1 vol.	. .	. .
Second quality	2 vols.	4 vols.	1 vol.	. .
Third quality	2 vols.	6 vols.	3½ vols.	. .
Concrete	1 vol.	1 vol.	. .	1¼ to 1½ vols.

	Analysis of Trass from Germany.						Puzzolana.					
Origin:	Plaidt. Tuffstone.	Kruft. Tuffstone.	Brohl. Tuffstone.	Brohl. Mountain Trass.	Weibern. Leucittuff.	Seven Mountains. Trachytuff.	Azores. St. Miguel.	Azores. Terceira.	Azores. St. Miguel "Teinn."	Italy. Naples.	Italy. Civitia Vecchia.	Santorin.
Analyst:	Zervas.	V. Menger-scbausen.	Berthier.	Kyll.	Kyll.	Kyll.	Chateau.	Zervas.	Zervas.	Stengel.	Berthier.	Feich-tinger.
Silica, SiO_2 . . .	53.58	55.28	57.00	61.10	67.60	59.40	54.70	57.73	60.90	60.91	44.50	66.37
Alumina, Al_2O_3. .	19.11	17.34	16.00	12.70	11.30	22.70	20.50	13.81	11.14	21.28	15.00	13.72
Iron Oxide, Fe_2O_3	9.24	3.90	5 00	10.20	5.20	2.50	6.30	12.02	12.78	4.76	12.00	4.31
Lime, CaO . . .	3.21	3.17	2.60	8.10	8.20	3.10	2.20	3.74	2.57	1.90	8.80	2.98
Magnesia, MgO .	0.30	0.87	1 00	1.90	2.80	0.80	1.70	1.73	1.45	0.00	4.70	1.29
Potash, K_2O . . .	4.84	4.70	7.00	2.10	0.60	3.50	} 2.20	3.21	2.64	4.37	1.40	2.83
Natron, Na_2O . .	1.87	3.80	1.00	2.10	0.50	2.80		2.76	2.74	6.23	4.10	4.22
Water, H_2O . . .	7.50	10.63	9 60	1.40	3.10	4.80	} 12.40	4.67	} 5.78	} 0.55	9.20	4.06
Loss	0.35	0.31	0.80	0.40	0.70	0.40		0 33			0.30	0.22

In the above analysis, all that is lacking to make a good material for hydraulic mortar is the lime, and this is therefore added to with sand,

In the United States the ordinary market limes make, when mixed with Puzzolana, very strong mortars; some of the best results having been obtained with common Rockland lime.

The lime should be slacked with about 40 per cent. by weight of water, two or three days before mixing with the Puzzolana, to give the unslacked particles a chance to be air-slacked. General Gillmore, in his work on limes above referred to, says: "Experiments seem to prove that fat lime slacked to powder will give better mortars with Trass and sand, or with Trass alone, if left exposed to the air for a month or more after slacking, than if made into mortar when perfectly fresh." After the lime has been slacked it should be screened through a sieve of 400 meshes per square inch. Of course, other kinds of lime may be used just as well in Puzzolana mortar. The right proportions of the mixture should be ascertained by previous experiments.

Unlike cement mortars, which have to be used soon after mixing, the Puzzolana and Trass, after the lime, sand and water are added to them in the proper proportions, can be left at least twenty-four hours undisturbed, and be worked over just before using, without injuring the quality of the resulting mortars. This is of great advantage in building operations, inasmuch as the quantity of the mortar for each day's work does not have to be so accurately determined.

As Trass and Puzzolana commence to harden only after the addition of the lime, they can be stored even in damp places for any length of time without deteriorating in the slightest degree. Trass that had been kept exposed to the atmosphere for three years and which was then mixed with one volume each of powdered lime and sand, gave a tensile strength at the end of five months of 204 lbs per square inch. This quality makes it possible to export Trass and Puzzolana without risk, whereas with Portland cement great trouble is experienced in the ocean voyage, either from dampness or overheating, and the cargo rarely arrives in as good condition as it was when shipped. The ability to keep Puzzolana and Trass also enable the engineer to carry on large works more advantageously, as he is not obliged to estimate so closely the quantity of cement required for each piece, and he can make better arrangements in regard to its purchase and storage.

To get a Portland cement mortar of equivalent strength to the Puzzolana, and near the price of it, large quantities of sand must

be added. This brings up the question of the weakening effect of certain sands upon cement mortar and, from some very carefully made German experiments, we find that the same cement mixed with fine and impure sands can lose two-thirds of its strength. The bad effect of the inferior sand upon a Puzzolana mortar would be less in proportion to the smaller amount of sand used.

Puzzolana and Trass mortars form very little "laitance" as compared with cement mortars; a very desirable quality when laying concrete in mass, under water, where cement mortars tend to separate in layers, according to the specific gravites of the component parts, which is not the case when Puzzolana or Trass is used.

The change of volume, either contraction or expansion, so common with cement mortars, is not observable with Puzzolana or Trass when the lime is perfectly slacked.

The following table, in which the quantities have been determined by very careful measurements, will enable any one to calculate for himself the relative economy of using Puzzolana and Trass mortars in preference to either Portland or Rosendale cement.

The weights of the three cements and of the lime and sand were obtained by filling a litre with each material and shaking the measure as they were poured in, until the litre would hold no more, thus insuring absolute compactness.

TABLE A.

	Weight: Kilograms.	Amount of water absorbed. Litres.	Amount of space occupied by solid material in one litre.	Space occupied by each material in a cubic metre of mortar.
Portland cement	1.63	0.480	0.520	520 litres.
Rosendale cement	1.40	0.500	0.500	500 "
Puzzolana or Trass	1.25	0.370	0.630	630 "
Sand	1.70	0.350	0.650	650 "
Powdered or slacked fat lime	0.72	0.600	0.400	400 "

TABLE B.

Average prices of mortar materials in New York.

			One cubic metre.	
		Costs.	Contains Kilo.	Costs.
Portland Cement	1 bbl. net, weighs 170 kilo.	$2.15	1630	$20.61.
Rosendale "	1 " " " 136.2 "	1.00	1400	10.27.
Pnzzolana or Trass.			1250	10.00.
Fat lime	1 " " " 136.2 "	0.70	. .	. .
Slacked to powdered gives 2.25 vols.			720	1.65.
Sand	1 cubic yard weighs 1315.0	0.65	1700	.87.

TABLE C.

One cubic meter of	Powdered fat Lime. Cubic metres.	Sand. Cubic metres.	Water, 25 per cent. by vol. cubic metres.	Amount of mortar. Cubic metres.	Total cost.	Cost per cubic metre.	Cost per cubic yard.	Tensile strength. lbs. per sq. inch. 28 days old.
Portland Cement.	. . .	1	0.500	1.67	$21.44	$12.84	$9.80	215
" "	. . .	2	0.750	2.57	22.28	8.67	6.62	163
" "	. . .	3	1.000	3.47	23.12	6.67	5.09	140
Rosendale "	. . .	1	0.500	1.65	11.10	6.72	5.13	116
" "	. . .	2	0.750	2.55	11.94	4.69	3.59	60
Puzzolana or Trass.	1	1	0.750	2.43	12.49	5.14	3.92	200
" "	1	1.5	0.875	2.88	12.91	4.48	3.33	187
" "	1	2	1.000	3.33	13.33	4.00	3.05	128

Tables A and B may be changed by substituting for the weights of the materials when compacted, the weights of the same when poured loosely into the measuring vessel, as, for example, the standard weights per struck bushel when measured by falling from a hopper placed at a uniform height. But this change will not affect the results shown in Table C relatively for the three cements.

The tensile strength for Portland and Rosendale mortars, given in the last column of Table C, is taken from Mr. Eliot C. Clarke's paper printed in the Transactions of the American Society of Civil Engineers, published in April, 1885. It was compiled from about 25,000 breakings of twenty different brands, and fairly represents the average strength of ordinary good cements of the two kinds. The amount of water used was just sufficient to make a plastic mortar, somewhat stiffer than is commonly used by masons, about 25 per cent. for neat Portland and 33 per cent. for neat Rosendale. The amount of water used by Mr. Clarke in his experiments being about the same as was used with the Puzzolana mortars, enables us to make a fair comparison. If less water had been used all the above figures would be more. Mixed with 20 per cent. water Puzzolana mortars composed of one volume each of Puzzolana, lime and sand, 28 days old, break at more than 200 lbs. per square inch.

The following tables give a summary of results in regard to the proportion of the compressive strength compared with the tensile strength, the latter being admitted at 100. The mixtures are made by volume.

Puzzolana or Trass.	Fat Lime	Sand.	Compressive strength.
1	¼	1	683
1	½	2	732
1	1	3	826
1	1½	4	810

With slow setting cement treated in the same standard manner, the results were:

Cement.	Lime.	Sand.	Compressive strength.
1	. .	1	825
1	. .	2	822
1	. .	3	789
1	½	4	808
1	1	6	770

The above figures prove clearly that Puzzolana or Trass mortar shows better proportions of compressive strength to tensile strength when a larger amount of sand is added, so as, by diminishing its plasticity, to render it more similar to cement mortar, and consequently be struck into the testing moulds like cement mortar. While the air can not escape as easily from the fat Puzzolana or Trass mortar as from the cement mortar, the density of the test cube, and consequently the strength, is diminished in a proportion which averages 98 : 100. Therefore, in practical work, where no ramming of the mortar takes place, the results will, in proportion, be more advantageous with Puzzolana or Trass mortar than with cement mortar. To test the density or impermeability to water, circular conical disks of 20 square centimetres surface at the smallest face, and 15 millimetres thick are made of standard mortar, and immersed into water to harden the same as for tensile strength test. By means of a rubber ring the hardened disk is tightly fitted into a cylinder in such a manner as to produce by an air pump a vacuum in the lower part of the cylinder underneath the mortar disk, while water is filled in the upper part of the cylinder, on top of the mortar disk. The water thus effects a pressure of one atmosphere upon the mortar disk. After 24 hours the percolated water is carefully collected and weighed.

Results 1. The mixtures being made by volume; the fat lime slacked to paste, and the mortar disks hardened for 6 weeks under water:

Trass or Puzzolana.	Fat lime.	Sand.	Water.	Water-pressed trough.
2	1	0	0.180	0.00 grammes.
1	½	1	0.150	0.03 "
1	¼	1	0.075	0.10 "
1	1	1	0.000	0.14 "
1	¼	2	0.150	0.14 "
1	1	2	0.050	0.06 "
1½	1	2	0.200	0.01 "
1	1½	3	0.075	0.59 "
1¼	1	3	0.200	0.29 "
1½	1	3	0.300	0.10 "
1	1¼	4	0.050	0.66 "

2. The fat lime being slacked to powder and the mortar disk hardened for four weeks under water.

Trass or Puzzolana.	Fat lime.	Sand.	Water.	Water-pressed trough.
2	1	0	0.800	0.10 grammes.
1	1	1	0.450	1.15 "
1	1	1	0.500	0.25 "
1	1	1	0.550	0.15 "
1	1	1	0.600	0.07 "

To surpass the quantity of water of the last mixture would be injurious, as the quantity of water and lime is of essential influence to the density of the mortar.

Cement-sand mortars thinned as in practical use are less dense, because the cement does not fill up as perfectly the spaces between the particles of the sand as is the case with Puzzolana or Trass and lime in Puzzolana or Trass mortars.

Slow setting cement of standard tensile strength and standard mixture, after four weeks' hardening under water, transmitted 1.25 grammes of water, and mixtures of

Cement.	Lime.	Sands.
1	. .	4
1	⅓	4
1	1	6

treated in the same manner transmitted all of the water. To Dutch and German engineers these well known facts have been of decisive importance in many of their large works, especially in the construction of sluices and basins.

The adhesive strength of mortar to stone is of great importance,

especially in concrete. In the following table the figures of adhesion have been established in connection with the compressive strength which is taken at 100.

The test specimens are prepared in the same manner as for compression tests. As bricks show too great a difference between each other, congenerous basalt pieces have been used for the concrete. To one volume of ready mortar, two volumes of basalt pieces have been added, after they had been immersed in water for sometime. The specimens were left to harden under water for 6 weeks.

Mortar mixture by volume.				
Puzzolana or Trass.	Fat lime paste.	Sand.	Water.	Proportion of the adhesive strength of the concrete.
2	1	0	0.180	108
1	½	1	0.150	101
1	¾	1	0.075	121
1	1	1	0.000	115
1	¾	2	0.150	109
1	1	2	0.050	126
1	1	3	0.100	90
1	1¼	3	0.075	109
1¼	1	3	0.050	95
1	1⅛	4	0.100	73
1	1¼	4	0.050	78

The mortars with more lime show mostly higher proportional figures in concrete than those with less lime. Therefore, a larger addition of lime should be made to mortar used in concrete than to that used without stones. While up to the admixture of two volumes of sand the concretes show higher strength than the mortars without stones, the adhesive strength decreases with larger addition of sand in such a manner that it does not even reach the strength of the mortar without stones.

By this it is easily understood that cement mortars, with much sand (as generally used, 1 volume of cement and at least 3 volumes of sand) attain by far inferior strength in concrete than the same cement mortars would show without stones. These differences in strength ought to be greater with cement mortars than with Puzzolana or Trass mortars, because, in consequence of their greater density, the Puzzolana and Trass mortars have more points of contact with the admixed stones than the more porous cement mortars.

Adhesion tests with cement mortar made into contrete and

treated in the same manner as with Puzzolana and Trass mortar gave the following results:

Cement.	Lime.	Sand.	Proportion of the adhesive strength of the concrete.
1	. .	3	76 : 100
1	. .	4	62 : 100
1	⅓	4	72 : 100
1	1	6	65 : 100

For the valuation of the mortar materials it surely merits consideration, that in most of the mortar mixtures used in concrete works, Puzzolana and Trass mortars yield a higher strength by the addition of the stones, while the more porous cement mortars show a much inferior strength, as it is found by the usual test of the strength of the mortar without stones.

As no large structure can be executed without interruption, the joining of the separate layers of mortar is of special importance. The more or less perfect junction of already hardened to fresh applied mortar is not dependent upon the final hardening of the mortar, but rather upon its adhesive capacity.

Experiments in that line have been made as follows: Specimens made as for tensile strength tests were at once immersed into water. After 24,36 etc., hours some of them were taken out of the water and divided into halves, while the other specimens remained under water to ascertain later their tensile strength. Each of the halves were put again into a mould, and the remaining empty half of the mould filled up again with fresh mortar, carefully pressed to the old half specimen and reimmersed at once.

The cement used for this test, according to standard test, left one day in the air, showed 16.85 kilos tensile strength. The less strength stated in the following table is caused by the necessary immediate immersion of the specimens.

TABLE I.

Mixture.	Medium temp. of water.	Tensile strength after 28 days. Kilos per square centimeter. Regular specimens.	Specimens joined after 24 hours.
1 Trass, 1½ fat lime paste. 3 Sand, without water.	19¼°C	15.00	12.00
Cement, standard mixture	19½°C	11.25	6.25
This answers the proportion of:			
Trass-Puzzolana mortar		100 :	80
Cement mortar		100 :	55

TABLE II.

Mixture.	Temperature.	Regular specimens.	Joined after 36 hours.
Trass, the same as in Table I.	15¼°C	13.25	9.25
1 Trass, 1 fat lime paste, 1 sand, and 5% water.	15 °C	14.50	11.00
Cement standard mixture	15 °C	9.50	4.00
This answers the proportion of:			
Trass mortar	1 . 1½ . 3	100 :	70
Trass mortar	1 . 1 . 1	100 :	77
Cement mortar		100 :	42

That Trass or Puzzolana mortar, even after so long an interruption of the work, makes as perfect a junction, as shown by the table, is certainly very important, and the only guarantee for impermeable masonry. It is more important yet with concrete work under water. Usual cement mortars often form very much "laitance," which has to be removed before new concrete may be put on. As the formation of "laitance" is but a consequence of decomposition of the mortar, it ought to diminish the hydraulic properties of the mortar. With the plastic Trass or Puzzolana mortars such decomposition and formation of "laitance" is almost unknown.

Hardening under seawater is by no means injurious to Puzzolana or Trass mortar. Even much higher strength is obtained than when hardening in soft water. This has been stated in many maritime works by the Governments of Germany, Holland, Portugal, etc. Taking the tensile strength of the mortar hardened in soft water at 100, the same mortar hardened in seawater showed the following results:

Trass.	Fat lime paste.	Sand	after 28 days hardening.
2 parts	1 part	. . by weight	111
1 part	1 "	1 part "	168
1 "	1 "	2 parts volume	132

At the Polytechnicum in Delft, Holland, tests were made by Professor van der Kloes, at the pretty low temperature of 7.9° C. yielding an average tensile strength after one month's hardening, with 2 parts Trass and 1 part of fat lime,

in soft water	in seawater
7.84 kilos	10.56 kilos per sq. centimetre
that means a proportion of:	100 : 135

Trass has been used in the construction of most bridges over the Rhine, Weser and Elbe, at the maritime works of the German Government, and especially in Holland and Belgium, the docks at Antwerp having required 60,000 tons. Trass was also used in building the large aqueduct that supplies the city of Verviers, including the enormous masonry dam, "le barrage de la Gileppe," in Belgium, about 25 years ago. To show how Trass and Puzzolana can hold their own as competitors with Portland cements, may be mentioned the fact that when, about 15 years ago, it was found necessary to build some hydraulic works, sluices, etc., for the improvement of the River Main, in close proximity to the celebrated Portland cement works of Dykerhoff and Schifferdecker, Trass was selected as the material to be used on account of its strength and cheapness, although it had to be brought about three hundred miles. Large contracts have been made for supplying the Chinese Government with Trass manufactured by D. Zervas' Sons, Cologne, Germany, owners of extensive tuffstone quarries and Trass mills near Andernach, Kruft and Brohl.

According to the official reports of the Board of Trade in Lisbon, Puzzolana was imported from San Miguel, Azores Islands, to Portugal, in 1801, and was there used with great success in the erection of important buildings. Of late years this Puzzolana has been used with great satisfaction in the following railroad constructions: East Railroad, South Railroad, and Central Railroad; in the harbors, docks and bridges in Porto, Lisbon, Ponta Delgada, etc.; also in the hospital, aqueduct and reservoir, together with many other structures in Lisbon and other cities in Portugal. In the harbor and dock works of Figueira, which required over five years to finish, the mortar was: one volume Puzzolana, one volume Alcantara lime, and one volume sand. This mortar got so hard that fire was produced when it was struck with a hammer.

Trass and Puzzolana have as yet rarely been used within the United States; probably because they have not been advertised enough. A few small works made with Puzzolana of the Azores produced excellent results, even under very unfavorable circumstances.

It may be proper at this point to mention but one report in regard to this. Mr. Henry S. Kearney, Chief Engineer of the Board of Electrical Control in New York, says in his letter of September 2d, 1887: "I can state that I put the concrete made of Puzzo-

lana in last fall in Green Point for foundation of a large engine, which has been running very satisfactorily since last spring. As I have not had any occasion to inspect it, there being no complaint, I can say that it is satisfactory. I consider the time (November and December) when concrete was placed, being very unfavorable, and my not being troubled since the engine has been running, very satisfactory test and very much in favor of the cement and its future use."

The writer of this article inspected the work mentioned. The block containing over 50 cubic yards was as solid as a monolith. The place where the block had to be put in was swampy, subjected to the effect of ebb and flood, and the foundation secured by but a small pile work. The weather was so cold that every morning a solid ice cover had to be removed from the work pit to put the concrete in, and the concrete consisting of:

1 volume of Puzzolana from the Azores,
1 " " Rockland lime slacked to powder,
1¾ " " concrete stones,

had to be used at once after mixing to prevent its freezing. All other cement work at the place had to be stopped on account of the great cold.

Some smaller Puzzolana concrete works at the same place showed all the same perfection.

Up to the present time real Puzzolana has not yet been discovered within the United States, where the geological conditions offer little expectation in that regard.

PRINCIPLES OF ELECTRICAL DISTRIBUTION.—II.

By FRANCIS B. CROCKER.

Constant Potential Parallel Systems. Parallel systems operating at constant potential are far more important in electrical distribution than series systems, since practically all incandescent lamps, a large proportion of arc lamps, and nearly all electric motors, are supplied by them. Constant potential circuits are usually more complicated than the simple series systems, there being only a single path for the current in the latter case, while with parallel connections there are a number of

branching paths. Furthermore, the maintenance of a uniform voltage over a large district is exceedingly difficult. The "drop" or loss of voltage, due to the resistance of conductors, is particularly objectionable in incandescent lighting, since the slightest decrease of potential produces a very considerable diminution of light. For example, the candle-power is reduced from 16 to 15, which is more than 6 per cent., when the pressure falls from 110 to 109 volts, or less than 1 per cent. Such a very small variation in pressure would hardly be appreciable in any other practical work, such as steam or gas distribution.

The drop in pressure produces three different effects in the lamps or other devices supplied by parallel circuits:

(1) All of the lamps receive a lower voltage than that generated by the dynamo.

(2) Some lamps may be supplied with a lower pressure than others.

(3) The potential at some lamps may vary when others are thrown on or off the same circuit.

The least harmful of these effects is the first, which merely requires the generator to be run at a little higher voltage, and does not necessarily involve any difference between the candle-power of the lamps, since the drop may be made substantially the same for all of them by some of the methods described later.

On the other hand, *variations* in the candle-power of lamps due to either of the last two effects are extremely objectionable and difficult to overcome. In order to study these problems let us take a specific case and assume that 100 incandescent lamps are to be supplied with electric current. They are supposed to be divided into five groups of 20 lamps each; each lamp requires a current of 110 volts and one half ampere and gives 16 candle-power; therefore one group takes 10 amperes, the total current being 50 amperes. The members of each group of lamps are connected in parallel in the usual manner, but will be indicated by a single line in the following diagrams in order to avoid confusion. These groups are assumed to be 200 feet apart in a straight line, making a total distance of 800 feet between the extreme groups, as shown in Fig. 4. The five groups of lamps represented by the light vertical lines are connected together by two conductors, which are shown as heavy horizontal lines. These conductors correspond to the so-called *mains* in electrical distribution systems, to which are

connected the *leads* or small branch wires actually supplying the lamps. The mains receive their current through *feeders* which connect them with the generating plant as represented in Fig. 12. As a general rule no lamps are connected directly to the feeders.

In the first case, represented in Fig. 4, the mains are supposed to be fed at one end, the feeding points being represented by short

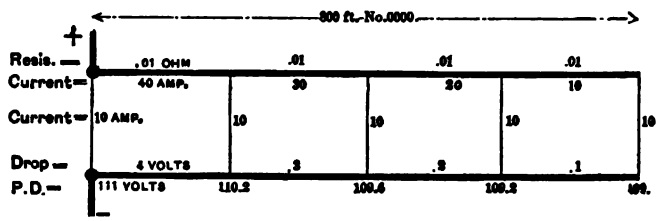


FIG. 4.—FEEDING AT ONE END OF MAIN; 1025 LBS. COPPER; 2 VOLTS MAX. DIFFERENCE BETWEEN LAMPS; 111 VOLTS AT FEEDING POINTS + AND —; 1.2 VOLTS AVERAGE DROP.

vertical lines marked + and — respectively. The mains are assumed to consist of No. 0000 wire, A. W. G., which would weigh 1025 pounds for the 1600 feet required. It will be seen that a potential of 111 volts, supplied at the feeding points, gives 109 volts at the other end, therefore no lamp receives a pressure more than one volt greater or less than the normal value of 110 volts.

In the second case, Fig. 5, the mains are supposed to be fed at their centres as shown. In this case No. 2 wire, weighing 321.5 pounds, gives almost exactly the same variations of potential as in the preceding case, the maximum pressure being 111 volts and the minimum 109.08 volts. This shows that a great saving of copper is effected by simply feeding the mains in the middle rather than at the ends. Theoretically, it would only require one quarter as much copper in the former case. This is easily seen when it is considered that the mains in Fig. 5, on each side of the feeding point are one half as long and carry one half as much current as those in Fig. 4, consequently the conductor has one quarter of the cross section to give the same drop. The weight is found to be slightly more than one quarter in the examples because the nearest regular size of wire was taken in each case, in order to make the examples as simple and practical as possible.

The next case, Fig. 6, represents the mains fed at opposite points. This is sometimes called the *Werdermann* system, after its inven-

tor, and sometimes the *loop* or *anti-parallel* method of distribution. In this case the same length (1600 feet) of No. 4 wire weighing only 202.2 pounds, gives an equally good distribution of poten-

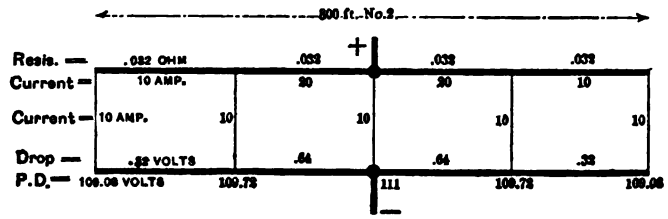


FIG. 5.—FEEDING AT MIDDLE OF MAINS; 321.5 LBS. COPPER; 1.92 VOLTS MAX. DIFFERENCE BETWEEN LAMPS; 111 VOLTS AT FEEDING POINTS + AND —; 1.3 VOLTS AVERAGE DROP.

tial. It is sometimes supposed that this arrangement must give a perfectly uniform potential at the lamps, since the sum of the distances of each lamp from the feeding points measured on the two mains is a constant. As a matter of fact, however, the middle lamps will receive a lower voltage than those at the ends, as shown in the diagram. This is due to the fact that the middle lamps are supplied through the portions of the main conductors which carry heavy currents, and in which the drop is greatest. For example,

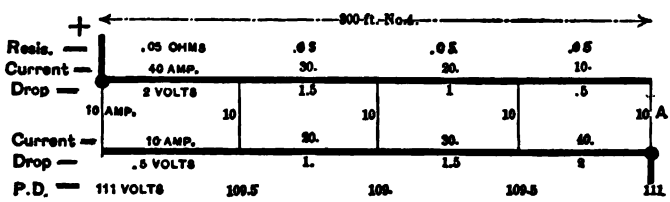


FIG. 6.—FEEDING AT OPPOSITE ENDS OF MAINS; 202.2 LBS. COPPER; 2 VOLTS MAX. DIFFERENCE BETWEEN LAMPS; 116 VOLTS BETWEEN FEEDING POINTS + AND —; 6 VOLTS AVERAGE DROP.

the drop on the mains in the case of the central group of lamps is $2+1.5+1.5+2=7$ volts, but for the end group of lamps it is only $2+1.5+1+0.5=5$ volts. It is possible, however, to secure a perfectly uniform pressure at all points between the mains, if their cross-section is made proportional to the current in each section. In this way the drop in each section will be the same, and every lamp will be supplied with exactly the same pressure. The use of these tapering, or so-called "conical," conductors is somewhat

objectionable from a practical point of view, since it would require considerable extra trouble to lay them; but it is evidently practicable in many cases to proportion the size of each length of wire to the current that it must carry without involving much additional

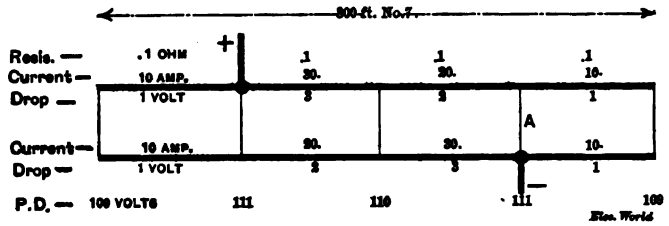


FIG. 7.—FEEDING AT DISTRIBUTED POINTS ON MAINS; 101 LBS. OF COPPER; 2 VOLTS MAX. DIFFERENCE BETWEEN LAMPS; 116 VOLTS BETWEEN FEEDING POINTS + AND —; 6 VOLTS AVERAGE DROP.

trouble, since the wire is laid in sections between cut-outs at which its size can easily be changed. For example, each of the sections of the mains shown in Fig. 6 could consist of a different size of wire.

In the next example the mains are fed at distributed points as represented in Fig. 7. In this case No. 7 wire, weighing only 101 pounds, gives no greater variation in voltage (*i. e.* one volt from the normal) than No. 0000 wire, weighing 1025 pounds in Fig. 4. These examples show the great difference that is made by changing the points at which the feeders are connected to the mains.

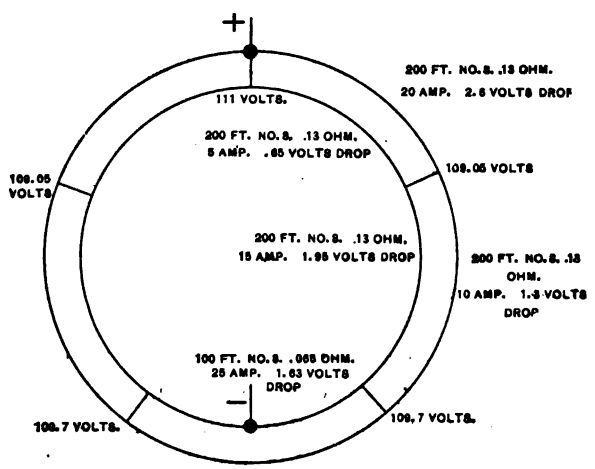


FIG. 8.—CLOSED RING; 2000 FT. NO. 8; 100 LBS. COPPER; 115.23 VOLTS BETWEEN FEEDING POINTS + AND —; 1.95 VOLTS MAX. DIFFERENCE BETWEEN LAMPS; 5.53 VOLTS AVERAGE DROP.

It should be carefully noted, however, that in both the last two cases (Figs. 6 and 7) the feeders must supply 116 volts to the mains instead of only 111 volts, as in the two previous examples (Figs. 4 and 5). In Fig. 6, for instance, the difference of potential between the feeding points + and — must be 116 volts, in order that the end group A shall receive 111 volts, since there is a drop of

$$2 + 1.5 + 1. + 0.5 = 5 \text{ volts}$$

in the upper main. Similar reasoning applies to the group A in Fig. 7. This necessity for supplying a considerably higher voltage at the feeding points of the mains is disadvantageous in two respects. First, it involves a loss of power in watts equal to the extra pressure multiplied by the total current, and, second, it may allow great variations in potential to occur when a large number of lamps are thrown on or off the circuit. For example, if all the lamps except one were put out, the remaining one would receive practically the full pressure of 116 volts. This may be overcome by reducing the voltage of the feeders when lamps are disconnected, either by automatic or hand regulation, employing some of the methods described later.

A further extension of the principles shown in Figs. 6 and 7 is indicated in Fig. 8, in which five groups of lamps are connected across the mains which form complete circles, being fed at diametrically opposite points. In this case 2000 feet of No. 8 wire weighing 100 pounds is used instead of 1600 feet as in the previous

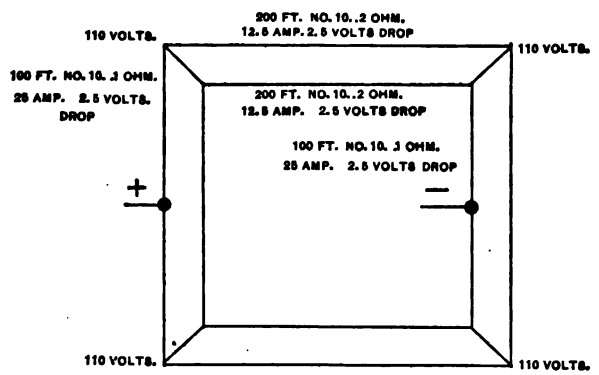


FIG. 9.—CLOSED SQUARE; 1600 FT. NO. 10; 50.3 LBS. COPPER; NO DIFFERENCE BETWEEN LAMPS; 117.5 VOLTS BETWEEN POINTS + AND —; 7.5 VOLTS AVERAGE DROP.

examples. A similar arrangement is shown in Fig. 9, but the lamps are assumed to be divided into four groups of 25 lamps each. All the lamps receive exactly the same voltage, 1600 feet of No. 10 wire, weighing only 50 pounds, being required. This exact equality in voltage is due to this being a special case in which the lamps happen to be symmetrically placed with respect to the feeding points. In Fig. 6, for example, the second and fourth groups of lamps have exactly the same voltage since they are equally distant from the feeders. But the pressure at the feeding points is higher in Fig. 9 than in any of the other cases.

Individual Conductors. The most certain way to obtain a constant voltage in parallel distribution is to provide each lamp or group of lamps with its own particular conductors. One arrangement of this kind is illustrated in Fig. 10, five groups of lamps,

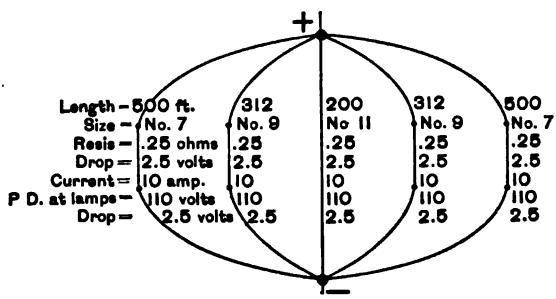


FIG. 10.—INDIVIDUAL CONDUCTORS. UNEQUAL LENGTHS; 186 LBS. COPPER; NO DIFFERENCE OF VOLTAGE BETWEEN LAMPS; 115 VOLTS BETWEEN FEEDING POINTS, + AND —; 5 VOLTS DROP.

each taking 10 amperes and placed 200 feet apart, being assumed as in the previous examples. The feeding points, marked + and — are supposed to be located at some distance from the lamps, as shown. The pair of conductors that supply each group is so proportioned in size and length that the drop has an equal value for all of the groups. This condition will be secured if the cross-sections of the various conductors are respectively proportional to their lengths. For example, if a conductor is twice as long as another, it should have double the cross section, so that the resistance of the two will be equal. If the currents are not the same for the different conductors, the cross sections should be further modified in proportion to the currents. It other words, for all of

the pairs of conductors $\frac{il}{a}$ should have the same value, i being the current in amperes, l the length and a the cross section.

It is not apparent what advantages this plan of using individual wires has over the arrangements already described, the weight of copper being even greater than that in Fig. 7, for example. The answer is to be found in the fact that the groups of lamps in Fig. 10 are not only equal in potential when all are burning, but they are also independent of one another, the turning on or off of one or more groups not affecting the others, provided that the voltage at the feeding points + and — is kept constant. In the preceding cases, the throwing off of some lamps would vary the pressure of all the others. In fact, it was pointed out that disconnecting every lamp but one would raise its potential practically the whole amount of the drop, which was five or six volts in some instances. It was also stated that the remedy for this variation consists in regulating the pressure at the feeding points. Thus it appears that it is necessary to maintain a constant voltage at the feeding points with some arrangements of conductors and a variable voltage with others. These questions will be considered later under feeder regulation.

Fig. 11 represents another example of individual conductors, but in this case each group of lamps is supplied through the same total length of conductor, *i. e.*, 800 feet of No. 8 wire, having 0.5 ohm resistance. Consequently the drop is five volts for all, since each group takes 10 amperes. The advantage of this plan over that shown in Fig. 6, which it somewhat resembles, is the freedom from interference already explained. It should be noted, however, that in either Fig. 10 or 11 the turning off of a portion of the lamps in one particular cluster would affect the remaining ones in that group. In order to secure complete independence of operation for every lamp in a system, it would be necessary to provide each one with its own individual wires. This is practically out of the question in almost all cases, but it can be approximated more or less closely, the tendency in the best practice being to sub-divide the circuits and reduce the number of lamps on each, as far as economy and simplicity will reasonably allow.

Regulation of Pressure. The feeding points in the various diagrams might in some cases be supplied with current directly from the generator, the voltage of the latter being varied in accordance

with the number of lamps connected. With the arrangement shown in Figs. 4 and 5 it would not be necessary to alter the potential at all, because no lamp could receive more than 111 volts, which is the pressure of the feeding points, even if all but one lamp were turned off. The large amount of copper used in these cases saves the trouble of regulation, and often might be worth the extra first cost. This is practically the way that the majority of isolated plants are operated, the size of the wires being suffi-

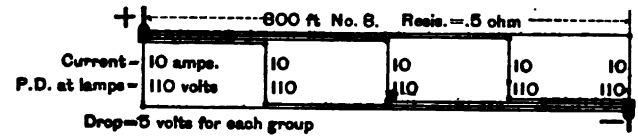


FIG. 11.—INDIVIDUAL CONDUCTORS; EQUAL TOTAL LENGTHS; 200 LBS. COPPER; NO DIFFERENCE OF VOLTAGE BETWEEN LAMPS; 115 VOLTS BETWEEN FEEDING POINTS + AND —; 5 VOLTS DROP.

cient to limit the drop to a small amount, so that the dynamos can run at a fixed voltage. As a matter of fact, however, the percentage of drop is usually too great to make this a very satisfactory method. If, for example, the wiring is designed for 5 per cent. drop at full load, and the dynamo generates 115 volts, the lamps will then be supplied with the normal pressure of 110 volts. But when nearly all the lamps are disconnected, the remaining ones may receive almost 115 volts, which would rapidly destroy them, besides causing disagreeable fluctuations in candle-power. As a compromise, the dynamo might be run at 112.5 volts, but at full load this would cause the lamps to burn quite dimly when the greatest light is required. The natural tendency to operate incandescent lighting plants at an average voltage is largely responsible for the poor illumination that is often observed, the lamp filaments being usually a dull yellow, and sometimes only red. But it is a false economy to prolong the life of the lamps at the expense of light. An increase of 10 per cent. in light for 500 hours is worth 50 cents at ordinary central station rates, which is enough to buy two new lamps. In other words, the electrical energy costs one cent per hour and the lamp only about $\frac{25}{500} = \frac{1}{20}$ cent per hour, hence it is very unwise to save the latter at the expense of the former. Furthermore, lamps tend to deteriorate in efficiency and give less light after a certain time. In short, for several reasons,

it is unwise to run them below their full rated voltage. These difficulties may be avoided either by regulating the generator by hand or by employing an "over compound" dynamo designed to automatically increase its voltage by an amount equal to the percentage of drop at full load.

With any of the arrangements represented in Figs. 6, 7, 8 and 9 the regulation of the generator would be practically necessary, since the potential at the feeding points is 115 volts or more at full load, which would be excessive at light loads. But by increas-

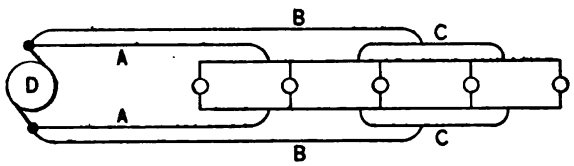


FIG. 12.—ARRANGEMENT OF FEEDERS.

ing the size of the conductors the drop can be reduced to a small amount, say 2 per cent or less, so that it is not required to vary the feeding voltage. This applies not only to these cases, but to almost any possible system, demanding, however, a large quantity of copper.

The individual conductors, shown in Figs. 10 and 11, do not involve any regulation of pressure, the feeding points being maintained constantly at 115 volts, and each group of lamps always receiving 110 volts when it is turned on.

Feeders.—In almost all practical systems the feeding points indicated in the diagrams are at some distance from the generator, being connected to it by conductors which are called "feeders." These are quite simple, since they are laid in as direct a path as possible, and do not usually have any branches or lamps connected to them, being represented by the feeders *AA* in Fig. 12. Occasionally they are divided at the end like the feeders *BB* into two or more branches *CC* which lead to distributed points on the mains in order to equalize the pressure more perfectly. The portions *CC* are commonly called *sub-feeders*.

Feeder Regulation. It has been shown that it is generally necessary to regulate the voltage at the feeding points to make up for the variable drop on the mains. When feeders are employed the regulation of the potential at the generator should be sufficient to

compensate for the drop on the feeders also. If there is only one pair of feeders, or if they are all uniformly loaded, over-compound winding on the dynamo can be made to neutralize the total drop. But where there are several feeders which are differently loaded, it becomes necessary to provide some means for controlling them independently.

The various devices employed for this purpose are:

1. Feeder rheostats; 2. Auxiliary "bus bars," and 3. "Boosters."

The first of these methods consists simply in placing a rheostat or variable resistance in series with each feeder, as represented in Fig. 13, the current capacity of the rheostat being sufficient for the maximum current conveyed by the feeder. In operating such a system a certain amount of resistance R is introduced into the circuit of feeder A that is lightly loaded, in order that the pressure which it supplies to the mains shall not be too high compared with that of the more heavily loaded feeder B, which has less resistance inserted. Thus by adjusting the arms of the rheostats R and S, the voltage at the ends of the feeders A and B may be made equal for all loads, or the potential at the end B may be raised a little above that of A in order to make up for the greater drop in the mains at H than at F.

The voltage at the further ends of the feeders may be determined by running extra conductors WW, called "pressure wires," from

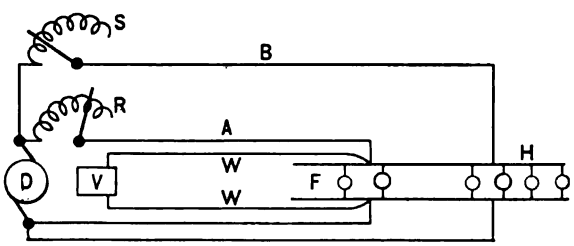


FIG. 13.—FEEDER REGULATION BY RESISTANCE.

the generating plant to the point at which the feeder is connected to the mains. The actual potential is read directly on the voltmeter V, since the current in the wires W W is so little that there is no appreciable drop upon them even when they are quite small. Another method consists in subtracting the drop IR on the feeders from the voltage V at the generators, that is, the potential at the ends of the feeders $P = V - IR$, in which I is the current and R

the resistance of a given pair of feeders. For this purpose an ampere-meter may be put in series with each pair of feeders, and it can be calibrated to give the drop upon them by simply multiplying its scale numbers by the total resistance of the two feeders. A still more perfect device is the so-called compensated voltmeter. This has the ordinary coil which measures the voltage of the generators, and also an additional coil that carries a certain fraction of the feeder current, the effect of the latter being to modify the deflections of the pointer, so that it indicates the pressure at the far end of the feeder.

Auxiliary 'Bus Bars are often employed in stations or plants of considerable size in order to avoid the loss of energy which inevitably occurs when "dead" resistance is used for regulation. This method is represented in its simplest form in Fig. 14, *C* and *D* being two dynamos, one of which *D* is connected to the main bus bar *F*, and generates the ordinary potential required to supply the shorter feeders or those which are lightly loaded, such as *B*. The other dynamo *C* runs at a higher voltage, and is connected to the auxiliary bus bar *E* for supplying the longer or more heavily loaded feeders, represented by *A*. The scope for regulation is still further increased by varying the pressure at either or both of the bus bars. This may be accomplished by hand or automatically, rheostats in the shunt field circuits of the dynamos, compound winding, or other well known means for controlling the E. M. F. of dynamos being employed for the purpose. It is evident that any number of bus bars may be used, being supplied with current by dynamos running at different voltages, and two or more

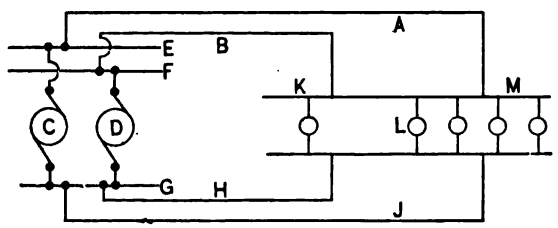


FIG. 14.—FEEDER REGULATION WITH AUXILIARY BUS BARS.

dynamos may be operated in parallel on any bus bar, in accordance with the demands for current. It is also obvious that several feeders may be connected to one bus bar. Each feeder is provided

with switches that connect it to any particular bus bar according to the load upon it.

A transfer bus bar is used to enable a feeder to be gradually shifted from one bus bar to another without the sudden variation in potential which would occur if it were thrown over directly by means of the switches mentioned above. This arrangement is indicated in Fig. 15, being similar to that shown in Fig. 14 but having a transfer bus bar P in addition to the main and auxiliary bars F and E. The latter is connected to the resistance T of a rheostat, the movable arm V of which is connected to the transfer bar P. The operation of shifting the feeder B from the main bus bar F to the auxiliary E when its load becomes large, is as follows: The feeder B is connected to the transfer bar at P, the rheostat T being previously open-circuited. The arm V is then moved clockwise until it comes in contact with the extremity of the resistance T. This connects the feeder B with the auxiliary bar E through the whole of the resistance T which allows a certain current to flow from E into B, the former having a

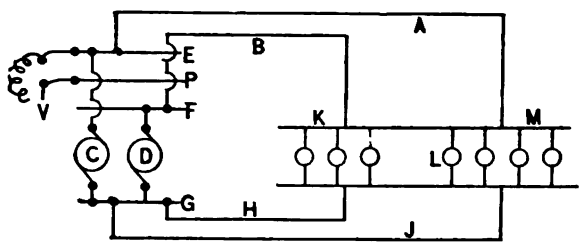


FIG. 15.—FEEDER REGULATION WITH TRANSFER BUS BARS.

higher potential than F, to which B still remains connected. The resistance T is then gradually cut out by the further movement of the arm V until the current supplied from the auxiliary E to the feeder B is equal to the load carried by the latter, when the connection between B and the main bus bar F is opened. The remainder of the resistance T is then cut out, which directly connects the feeder B with the auxiliary bar E, the transfer having been made without any disturbance of the system. In performing this operation the amounts of current are ascertained by having an ampere-meter inserted between T and E in addition to the ampere-meter that should always be placed in circuit with each feeder. The difference of potential between the feeders, bus bars,

etc., should also be indicated by voltmeters. The necessary instruments are assumed to be present in every case, but are omitted from the diagrams to avoid confusion, as they perform no active part in the operation of the system, their only function being to give information.

Where two or more feeders run to the same main and are provided with rheostats, one of them may be disconnected or transferred from one bus bar to another by first cutting in all the resistance of the rheostat in order to reduce the current and then opening the switch. The drop on a feeder being usually only a few volts, its circuit may be opened with practically no greater flash than is produced by any other circuit having a voltage equal to this drop, provided the remaining feeders are sufficient to carry the current without materially increasing the fall of potential upon them. In fact, it is possible to regulate, in this way, the potential on a system of conductors, some of the feeders being disconnected where the load is light and the pressure is high, thus tending to make the voltage uniform.

Feeder Regulation by Means of "Boosters" is represented in Fig. 16, in which D is the main dynamo generating the greater part of the electrical energy, and R and S are two small auxiliary dynamos called "boosters," connected in series with the dynamo D and the two feeders A and B respectively. Assuming that the main dynamo D generates a constant voltage, the variation in pressure required to regulate the feeders in accordance with the changing loads upon them is obtained by controlling the potential of the boosters R and S. This is usually accomplished by exciting the field magnets of each booster from the dynamo D, a rheostat being inserted in the circuit. Another plan is to provide the

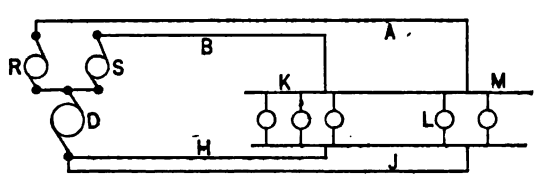


FIG. 16.—FEEDER REGULATION BY MEANS OF BOOSTERS.

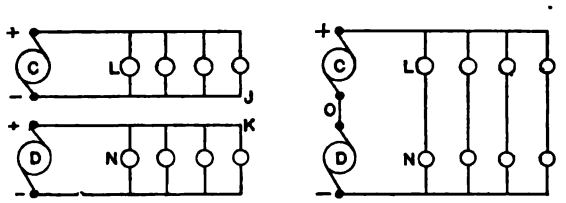
boosters with series-wound field magnets, in which case the voltage generated by each increases with the current flowing through it. With field magnets designed to work below magnetic saturation,

this gives an automatic regulation which is almost perfect, since the extra pressure produced by the booster may be made to exactly overcome the drop on the corresponding feeder for all loads, or it may be designed to also make up for some or all of the drop on the mains and leads. This method is quite similar in principle to that of compound-wound dynamos, but it acts upon the feeders individually, instead of upon the system as a whole. The main dynamo and the boosters may all be driven by one or more steam engines or other prime mover, or the boosters may be operated by electric motors supplied with current from the main dynamos. Boosters are sometimes used to reduce the voltage instead of raising it, in which case the main dynamo may be run at the average pressure required by the feeders, the potential in those that are heavily loaded being increased and being depressed in the lightly loaded ones. A booster which lowers the voltage by generating a counter E. M. F. acts as a motor and tends to develop power; consequently, if it is coupled with another booster it will drive it as a dynamo, provided that the energy absorbed by the former is slightly greater than that produced by the latter, in order to make up for mechanical and electrical losses in both machines.

Instead of having a separate booster for each feeder, as indicated in Fig. 16, two or more feeders requiring approximately equal voltages may be supplied from the same booster. In this way a large number of feeders may be regulated with only a few boosters, which are run at different potentials, the feeders being divided among them according to the extra pressure required. This is practically equivalent to a system having several auxiliary bus bars supplied with different voltages. In Fig. 14, for example, the dynamo *C* might be omitted and the higher voltage required for the auxiliary bus bar *E* could be obtained by connecting a booster between *E* and *F*. This is a more convenient arrangement in some cases, particularly in small plants, since it would only be necessary to run one main dynamo, the booster being driven by a motor fed with current from the dynamo.

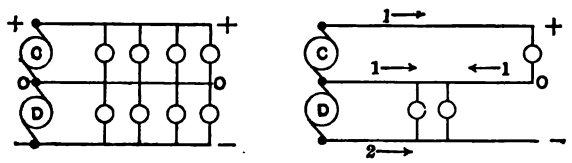
Three-wire System. The three-wire system which was independently invented by Edison and Hopkinson has for its object the saving of copper in distributing conductors. Until quite recently it was not considered practicable to use incandescent lamps designed for a pressure higher than 120 volts. This limited the potential at which parallel systems were operated and de-

manded conductors of large size and weight, particularly when the current is transmitted any considerable distance, as already shown in the examples given. When it is attempted to supply incandescent lamps in series, difficulties immediately arise, due to the dangers of high potential, the interference between the lamps and the imperfection of regulation, all of which were noted under the head Series Systems. The principle of the three-wire arrangement may be understood by first considering two entirely distinct two-wire circuits, as represented in Fig.



FIGS. 17 AND 18.—EVOLUTION OF THE THREE-WIRE SYSTEMS.

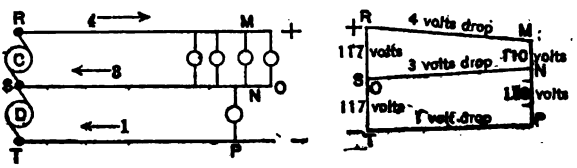
17. If the lamps *L* and *N* happen to be placed in the manner shown, it is evident that they may be connected in series of two each, as illustrated in Fig. 18, in which case the intermediate wires *J* and *K* become superfluous and are omitted. But when one of the lamps is turned off or burned out, its companion will also go out, hence a third wire, indicated in Fig. 19 by a line



FIGS. 19 AND 20.—THREE-WIRE SYSTEM.

marked *O*, is extended from the junction between the two dynamos *C* and *D*, in order to avoid this difficulty. This allows any number of the lamps to be disconnected without putting out those which remain. The extra conductor is called *the neutral wire*, and is usually marked *O* or ±, the latter symbol representing the fact that it is positive with respect to one conductor and negative with respect to the other. The neutral wire carries no current if the system is exactly "balanced" (Fig. 19), but when the amounts of current on the two sides of the system are not the same it supplies

the difference, whatever it may be, as represented by arrows and numbers in Figs. 20 and 21, each lamp being assumed to take one ampere. It should be observed that the flow of current may be opposite in direction in different parts of the neutral wire (Fig. 20). Another peculiar condition in three-wire circuits is the fact that the potential at certain lamps may actually be higher than that of the dynamo on the same side of the system. This is demonstrated



FIGS. 21 AND 22.—THREE-WIRE SYSTEM.

in the potential diagram (Fig. 22), corresponding to the arrangement of lamps shown in Fig. 21. Assuming the resistance of each of the three wires to be 1 ohm, the drop on the + conductor between *R* and *M* will be 4 volts with a current of 4 amperes. The drop between *N* and *S* on the neutral wire will be 3 volts, since 3 amperes flow back through it. With a potential of 117 volts at each dynamo, this gives 110 volts for the lamps between *M* and *N*. The drop on the — wire between *P* and *T* is 1 volt, hence the potential of the point *P* is 1 volt above that of *T*, but as *N* is 3 volts higher in potential than *S*, it follows that the pressure between *N* and *P* is 2 volts greater than that delivered at *S* and *T* by the dynamo *D*. Therefore, the lamps at *M N* receive 7 volts less pressure and the lamp at *N P* is supplied with 2 volts more pressure than the potential difference at each dynamo.

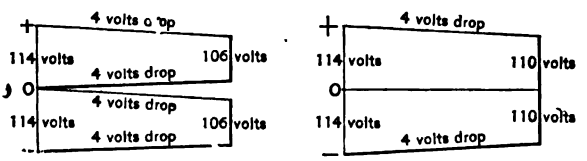
Advantages and Disadvantages of the Three-Wire System. The sole merit of this arrangement is the fact that it saves copper, the amount of this saving being determined as follows:

The circuit represented in Fig. 18 has two wires, while those in Fig. 17 employ four, hence the former requires one half as much copper as the latter, assuming the size of the wires to be the same. Furthermore, the percentage of drop in Fig. 18 will only be one half as great as that in Fig. 17, the explanation of this fact being given in Figs. 23 and 24, which show the distribution of potential in the two cases. In the two-wire circuits (Figs. 17 and 23) there will be a drop of four volts on each wire, assuming four amperes of

current and one ohm of resistance for each, and the lamps will receive 106 volts with a pressure of 114 volts at the dynamos, the drop being $\frac{8}{114}$, or 7 per cent.

The lamps on the three-wire circuits (Figs. 18 and 24) receive 110 volts with the same initial potential, *i. e.*, 114 volts, the drop being only $\frac{4}{114}$ or 3.5 per cent., or one half as much as in the previous case. It follows, therefore, if the wires in Fig. 18 have one half the cross section of those in Fig. 17, that the percentage of drop will be the same for both. Consequently Fig. 18 requires one half as many conductors of one half the size, or only one quarter as much copper as Fig. 17 for the same drop. If now the neutral conductor in the three-wire system (Fig. 19) be made the same size as each of the outside wires, the weight of the copper will be $\frac{1}{4} + \frac{1}{8} = \frac{3}{8}$ as much as in the two-wire circuits (Fig. 17), supplying the same number of lights at the same distance with equal drop. Since the neutral wire usually carries only a small current, it is often made one half as large as either of the outside conductors, in which case the weight of copper becomes $\frac{5}{16}$ that demanded by the two-wire system.

The great saving in copper, amounting ordinarily to $\frac{5}{8}$ or 62 5 per cent. is considered of such paramount importance that the three-wire system is usually adopted in electric lighting for low-tension distribution wherever the distances are considerable. In the case of low tension central stations this custom is very general, and even for large isolated plants the three-wire system is often



FIGS. 23 AND 24.—ADVANTAGE OF THE THREE-WIRE SYSTEM.

selected. It is also employed for the secondary wiring in alternating current distribution with transformers. The object in all cases is to save copper, which constitutes such a large item in the cost of nearly all electrical installations.

To offset this advantage, however, the three-wire system has the following disadvantages:

1. It is usually necessary to operate at least two dynamos or other sources of current.

2. It is necessary to lay and to take care of three wires instead of two.

3. The switches, cut-outs, measuring instruments, etc., are also more complicated.

4. The saving of copper stated assumes that the neutral wire carries no current.

But if all the lamps happen to be in use on one side of the system only, the copper should be the same as for a two-wire circuit. Even though the system be carefully kept balanced so that the current in the neutral conductor is only 10 per cent. of the total, the saving of copper would be reduced from 62.5 to about 50 per cent. for the same actual percentage of drop.

5. The *variation* in potential is aggravated by the increase that sometimes takes place (Fig. 22), which is impossible on a two-wire circuit.

When all these objections are considered it is somewhat doubtful if the reduction in the weight of copper makes up for them in some cases where the three-wire system is adopted. There is a strong tendency on the part of the purchaser, consulting engineer and contractor to give too great weight to the matter of first cost and too little heed to questions of convenience, labor involved, liability of accidents and many other factors that make up running expense. The three-wire system is unquestionably more complicated and difficult to install or operate, and it should not be selected unless the saving that it secures is surely sufficient to pay for these disadvantages. For low-tension distribution to distances of a mile it is practically necessary to employ it, but for isolated plants, where the length of wires is only a few hundred feet, its superiority is by no means certain, in spite of the very powerful argument which may be based upon the saving of copper.

The recent improvements in and applications of 220-volt incandescent lamps renders the three-wire system considerably less important than formerly, since it enables a two-wire circuit to be operated at 220 volts, the copper required being only two-thirds as much as for the ordinary three-wire system. To be sure, the latter can now be run at 440 volts, giving it the same relative advantage as before, but it is doubtful if such a high voltage is desirable for general use.

EXPLORATIONS IN THE GOLD FIELDS OF WESTERN COLOMBIA.

By F. C. NICHOLAS.

(Read before the New York Academy of Sciences, February 15, 1897.)

The auriferous gravels of Colombia are noticeably prominent on the western slopes and foothills of the Andes Mountains. In the interior parts of these mountains there are veins with quartz gangue and large deposits of auriferous pyrites; these seem of ordinary formation, but the gold-bearing sands and gravels of the lowlands present many peculiarities and at numerous points are illustrative of those conditions of difference between certain of the tropical auriferous gravels and those in countries where rain and flood do not exert so marked an influence. Along the western base of the Andes Mountains gold is found in gravel banks, in deposits of sand, in argillaceous alluvium and in all the rivers. In two instances I noted it in pebbles of a hard feldspar porphyry. The gold in each case was well defined, and could be distinctly seen in the rock mass just beside one of the light-colored inclosures. The pebbles were found on the same watershed but in different streams and a long distance apart.

Samples of gold washed in this country are at times so astonishing that the most extravagant claims have been made for its prospective output. I noted the following instances: Near Quibdo a prospecting party secured twelve pounds of gold from two or three yards of a mixed gravel and alluvial deposit. The outlook seemed promising and an extensive claim was located. The gold had been found in a low part of the valley and all the ground appeared similar to the spot where it was taken. The owners were enthusiastic and employed the twelve pounds of gold in opening up the property and, though they searched with great care, no more was found, not even a pennyweight.

A merchant at Quibdo, who has a comfortable fortune, claims to have taken nearly the whole of it from one spot where he dug down in a soft bed rock and secured rich returns.

As I was traveling through the country, my guides took me to a small brook that had cut deep in the bed rock and assured me that about $10,000 were taken from it in a few days.

My investigations in this country lead me to believe that these statements are correct, but that the general deposits of gold are not one-tenth part of what might be expected from such rich returns.

The formation, beginning from the Gulf of Darien and thence southward up the Atrato River, is a long stretch of swamps and alluvium to Quibdo; at this point low gravel beds, carrying gold, are found, and further on, near Lloro the bed rock is first seen. It rises abruptly from the river and stands in a precipitous bluff, its upper outline being a gentle anticline and the total elevation appearing to be 80 to 100 feet. Opposite this cliff there is a broad flat covered with gravel left by the river as it gradually encroached on the cliff and cut its way to new channels. Such flats are numerous and must be very rich in gold, but as the bed rock is well below the water-line they are not available, excepting for a pumping proposition.

The bed rock is very soft and appears to be an extensive aqueous deposit of eroded volcanic material mingled with sand and alluvium. It is very soft at places and a knife can be thrust in it several inches. The whole country along the western base of the Andes appears to be underlain by this formation. At Lloro, well defined strata of gravel are found in the bed rock, these are conformable to its general bedding and mark distinct lines extending for long distances. The pebbles are rather small as an average; they are of slates, quartzites, porphyries, trappean rocks, etc., and are well water worn. The cementing material is the gray sediment and alluvium of the general formation. I examined these cemented beds of gravel for gold, but did not find any.

To the south these gravel strata appear to deepen continuously. At Lloro on the Atrato River they are a few inches thick; on the San Juan River they have increased to several feet and at Buenaventura the finer sediments have disappeared almost entirely and all the cliffs are a mass of cemented gravel somewhat larger but in appearance identical with the narrow strata on the Atrato River far away northward.

This might be taken for the remains of an ancient drainage system of great proportions flowing toward the north; the lines of sediment along the cliffs indicating heavier material deposited back of Buenaventura gradually diminishing to lighter sediments along the Atrato, and finally alluviums along the same river further north. Such a drainage system could not have existed unless a great

stretch of land had formerly extended out into the Pacific Ocean. It is more probable that these gravel cliffs and sediments mark a stage somewhat similar to the terrace formations of the Atlantic States but probably formed at an earlier period and indicating the gradual recession of the waters of the Pacific.

At Buenaventura they are well mixed and common to all the formation because they here encountered the full force of the ocean; 'urther to the north they were partly protected by embayments, and strata of sediment and gravel gradually resulted. Crossing the Atrato and its affluents the appearances are that the gulf of Darien had formerly extended a great distance up what is now the valley of the Atrato. Here the waters were more quiet and finer sediments and narrow strata of pebbles might naturally be expected.

The material is a volcanic sediment because of the abundance of volcanic material from the Andes Mountains. The deposit is evidently very deep. At one place I took aneroid readings that indicated a cliff 260 feet high all of the same sediment and of uniform appearance.

The San Juan River flowing south and the Atrato River just over a low divide flowing north have made deep excavations since the uplift of this formation and the exposed strata appear to be continuous from one to the other. At the time these sediments were deposited there was probably some connection between them, as indicated by sediments at points on the divide, but on each side of it a separate deposit was formed under similar conditions and to-day the coincidence of different rivers eroding in one north and south line causes a marked resemblance to an ancient drainage system toward the north.

It is quite evident from the general outline that the present embayments were much more extensive even in recent times and this gives the clue to the formation of the different strata of gravel and fine sediment.

In all this sedimentary formation there is nothing to indicate gold and how it came to find a place in this district is a difficult question. I could not find any in the soft bed rock nor in the cemented gravels, yet it is abundant in all the rivers. Overlying the bed rock and covering an extensive district there is a shallow deposit of gold bearing gravel more angular than that in the bed rock strata. This gravel is mixed with clay and alluvium and contains the remarkable concentrations that have been noted.

Overlying this superficial gravel there are remnants of extensive clay deposits found in the steep eroded ridges at some places and entirely wanting at others. Angular gravel is found in this clay, pebbles of dark colored siliceous slates predominating, and at widely separated points I took samples of gold, though not enough to indicate profitable placer ground.

I found gold in this region under three conditions: (1) in all the rivers where it is well water worn; (2) in the shallow superficial gravels overlying the bed rock where it is rather angular; (3) in the clay and alluvium lying on the superficial gravels but only in very limited amounts. The gold from this deposit is sharply angular. Aneroid readings indicate about 90 feet of this clay. The gravels underlying the clay indicate that it is sedimentary, the angular gravels inclosed in it indicate brief periods of irregular sedimentation during which gold could have been brought down and deposited with other material.

The upper stratification of this region is: (1) the clay deposits overlying; (2) the superficial gravels, and (3) a deep sedimentary deposit of alluvium and volcanic material with gravel strata, all lightly cemented together. In the valley of the San Juan River there is a group of small peaks composed of some light-colored intrusive rock, rising abruptly from low alluvium gravel beds and swamps which were evidently formed around them. Some of the mountains east of the low divide also rise abruptly, and at one point apparently reach 900 feet elevation and are capped by what appears to be limestone.

To the east, as one approaches the Andes, the sedimentary rock is gradually lost among intrusive formations. These are of varied texture and appear like plagioclase rocks, melaphyres and syenites that are at times decomposed to such an extent that they can be dug out with the fingers, yet still maintaining the appearance of the original rock. Near these intrusions the bed rock becomes tilted and appears to be slightly metamorphosed, at some points indicating intrusions after it had been formed.

So far as I could ascertain, these intrusions are entirely barren of gold, and the numerous prospecting parties that have searched all through the most westerly undulations of the Andes, have been entirely unsuccessful.

Above the headwaters of the San Juan River there is a great intrusive mass, a mountain called the Tacamaca; it has a most

picturesque outline and appears almost barren of vegetation. It presents only rugged rocks rising four or five thousand feet above the foothills. It has never been explored and probably never can be. There are strong reasons for believing that similar but less important intrusions extend irregularly all along the western base of the Colombian Andes and that much of the country below them was elevated at their intrusion. These outlying mountains appear to be barren of gold, though auriferous gravels are found on or about them and nuggets have been taken at places near their summits, and these must have been deposited before the ridges on which they were found were intruded.

The periods of formation in this region are rather obscure, the volcanic sediments with alluvium in the bed rock mark the erosions subsequent to a long period of volcanic activity in the Andes. The overlying gravels mark a second series of deposits, indicating from the absence of volcanic material a different and less extended place of origin. The presence of gold in this gravel suggests that the rich deposits of the Andes had been formed and were being eroded. While this was taking place seismic action and resulting irregularities of surface probably occurred, and in the lower elevations or in places of subsidence sedimentary clays and some gravel and gold could have collected. Then came the upheaval of the Tacamaca and other intrusions along the base of the Andes which have cut off the lowlands from the gold-bearing regions of the interior.

It has been generally reported that gold is brought down annually from the Andes Mountains to the lowlands of western Colombia. This is correct in some instances and formerly it must have been the case, but in later days intrusions have been interposed between the gold mines of the interior and the auriferous gravels of the lowlands to the west.

To illustrate this condition I have in mind the river or low gravels of California, if ridges had been intruded along the western base of the Sierra Nevada Mountains; in recent times the auriferous gravels would have been elevated and, though the intrusive ridges would probably have been barren of gold, auriferous sands and gravels would have been found among them, perhaps, near their summits. This is what happened below the Andes in Colombia and prospecting parties looking for the original formations from which the gold in the lowlands has come, would do well to go further back among the mountains.

The gold in the lowlands has been concentrated in the most convenient places, and this has given rise to some erroneous impressions as to the richness and extent of auriferous gravels in this, and similarly in other tropical gold deposits. Rich placers worthy of attention are to be found in many parts of tropical America, but if the extravagant reports and calculations that have been made as to the probable yield were correct, gold would become as abundant and unstable in value as silver. The reasons why gold is concentrated locally are excessive floods and heavy rains which cause secondary local movements in a deposit of gravel without particularly changing its appearance. A flood may bring down an extensive bar of gravel carrying gold. The rains after the flood has subsided, are sufficiently heavy to cause small erosions and sorting of material quite different from that which takes place under continuous action in an ordinary river and resembles somewhat the action of the waves on the beach sands of the Pacific, which cause secondary concentrations of gold. Gravel may be brought down by successive floods and sorted by intermediate rains and a remarkably rich zone in the gravel results or one side of an extensive gravel bank may be noticeably productive.

It is a common mistake to overlook this sorting action of the intense rainy season and to suppose that the rich spots are a sample of what might reasonably be expected to continue all through the gravel deposit, yet the zone in which the gold is found may be almost barren a short distance further on.

I do not state that there is any less gold in South America, but I do say that where gravel deposits have been subjected to the heavy rains of that country either in the present or in more remote times, the gold has to an unusual extent been concentrated in depressions or along zones of drainage and that a more extended prospecting is required before a reasonable estimate can be made as to the value of such deposits, and, further, that in order to make prospecting successful the drainage zones must be traced out and samples taken from a line that will cut across such zones or concentrations and extend a considerable distance either side of them. This argument applies also to the rivers, where excessive changes with the seasons from flood and torrent to quiet, and, at times, almost stagnant water, have brought the gold under varying conditions down to the deeper places. Some of these places are fabulously rich, but the reports claiming that whole rivers are

similarly endowed on all their bars and gravel beds are miscalculations. The gold fields of tropical America are attractive, but if nuggets are found on outlying ridges, it would be well before spending much time and money looking for the veins, to examine carefully in order to learn if such ridges had not been intruded after the gold had been deposited, and if rich placers are found, it would be safe to prospect them carefully, before setting up expensive plants, and make sure that such apparently enormous deposits of gold are not secondary concentrations in convenient local depressions or along zones of drainage, because the well-known tendency of gold to form concentrations under aqueous influence has manifested itself to such an extent and under such varying conditions in tropical America, that auriferous gravels in that part of the world are frequently very deceptive.

I have spoken of a low divide between the waters of the Atrato River flowing north and those of the San Juan River flowing south. Here a very nearly continuous connection between the two oceans has been formed. The route is up the Atrato River to the Quito River, up the Quito River to the divide, where in very wet weather a canoe can be forced across a series of swampy places, without unloading it, to the San Pablo River, thence down the San Pablo to the San Juan and out to the Pacific.

The rocks are so soft in this district that the divide is probably the result of erosion to a very considerable extent, though the general outline and the sedimentary rocks indicate that in this district the continents of North and South America were once separated.

I have crossed and re-crossed the Isthmus and Central America a number of times, but have never found sediments at any other point that appeared at all continuous. As to the period in which this strait was filled up, I should say, judging from the deep erosion and the intrusive ridges, that it was in early Tertiary times and that seismic action has probably caused the subsidences.

The problem is complicated, but this much can be stated: There are sedimentary formations beginning below the Gulf of Darien, which, though eroded and much disturbed at places, are, under varying conditions, continuous to and across a low divide, which separates the affluents of the Atrato flowing north to the Gulf of Darien from those of the San Juan River flowing south to the Pacific Ocean.

AN INTRODUCTION TO THE STUDY AND EXPERIMENTAL DETERMINATION OF THE CHARACTERS OF CRYSTALS.

By ALFRED J. MOSES, Ph.D.

1. THE GEOMETRICAL CHARACTERS.

It is a general property of definite chemical substances to assume at solidification regular forms bounded by planes and observation has proved that the forms which occur are related to each other and characteristic of the substance.

The geometric study of crystals has for its purpose the grouping of crystals into series, each of which shall consist of the forms in which one substance can appear; the determination of the angles between the faces of crystals, and from these the elements and symbols of the faces, or conversely the determination of the form and angles from the elements and the face symbols.

The term crystal originally meant the angular forms of the substance called rock crystal, Figs. 1 and 2, which, according to Pliny,* was only "water frozen by the most excessive cold and

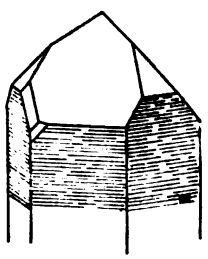


Fig. 1.

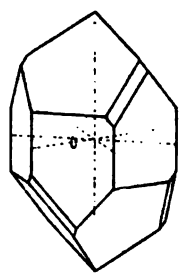


Fig. 2.

found only in places where snow is changed into ice." The angular shapes of this substance and of garnet,† beryl and possibly diamond, were known to the ancients, but were regarded as accidents and no general property was suspected.

* Quoted by Romé Delisle, *Essai de Crystallographie* (1772), p. 3.

† "There is also an incombustible stone found about Miletum which is of an angular shape, and sometimes regularly hexangular; they call this also a carbuncle." Theophrastus's *History of Stones.* Trans. by Sir John Hill, p. 77.

In 1568 WENTZEL JAMITZER,* a Nuremburg goldsmith, developed in perspective over one hundred and forty simple and complex shapes from the geometric tetrahedron, octahedron, cube, dodecahedron and icosahedron by replacing all similar edges and angles by one or more planes, and the famous astronomer KEPLER, in 1619, developed a similar series of figures. Many of these shapes correspond to crystals, and the method of modification may have suggested to Romé Delisle the method used by him more than a century later.

The development of chemistry from alchemy was accompanied by the study of many salts, the solutions of which, on evaporation, yielded regular and constant shapes which were suspected to be to some extent at least characteristic of the salt, for LIBAVIUS,† in 1597, stated that the nature of the saline components of a mineral water could be ascertained by an examination of the crystalline form of the salts left on the evaporation of the water.

In 1669 NICOLAS STENO,‡ a Danish anatomist, announced that if different specimens of rock crystal were examined, it would be

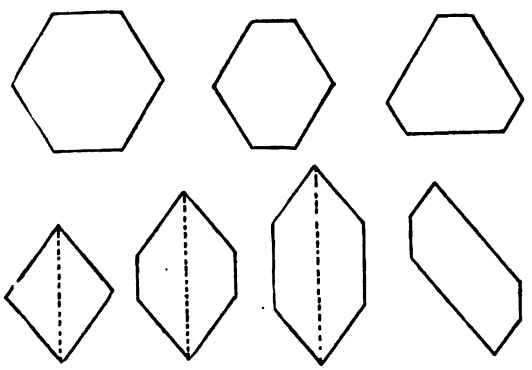


FIG. 3.

found that in spite of the variation in the relative size of the faces and in the shape of the crystal there was *no variation in the angles between the faces.* This he illustrated by figures of sections at right-angles to prism edge and others of sections at right angles to an edge between a prismatic and a pyramidal face, as shown in Fig. 3.

*Perspectiva Corporum Regularum, Quoted in Marx's *Geschichte der Krystalkunde.*

†Roscoe & Schorlemmer's *Treatise on Chemistry*, I. 705.

‡De solido intra solidum naturaliter contento dissertationis prodromus. Florentiæ, 1669: English translation, London, 1671.

A statement showing a very considerable advance from this was made by DOMINICO GULIELMINI in 1704, who asserted that every salt had its peculiar shape which never changed and that even in imperfect and broken crystals the angles were constant.

TORBERN BERGMAN* records that his pupil GAHN having broken a piece of Dogtooth Spar observed that it divided into little rhombohedra. In studying this, Bergman found that by laying together these rhombohedra in certain ways he could build up either a hexagonal prism terminated by this form or the common scalenohedron of calcite, or a form like the rhombic dodecahedron, all of which are shown in Fig. 4.

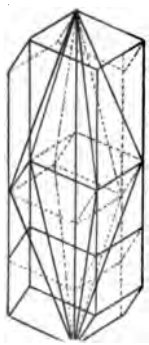


FIG. 4.

From this he deduced that there was a relation between outer form and inner structure and that the constituent parts of all crystals could be referred to a very small number of primitive forms which could be found by breaking the crystals.

In the preparation of models of crystal forms ROMÉ DELISLE, about 1783, measured† the interfacial angles directly with an application goniometer devised by Carangeot for this purpose. He described over four hundred crystal forms and formulated the now universally accepted law of constancy of interfacial angles as follows:‡ "*In spite of the numberless variations of which the primitive form of a salt or a crystal is capable, one thing never varies, but is always constant in each species, namely: The angle of incidence or the respective inclination of the faces to each other.*"

The law of symmetry may also be said to be based on a law of Delisle. "Every face has a similar face parallel to it."

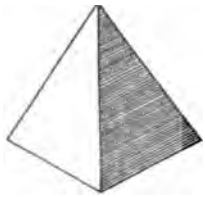
Delisle also developed Bergman's idea of primitive form and by a method similar to that of Jamitzer derived a series of secondary forms from each primitive by replacing the edges or angles of the primitive form by single planes or groups of planes in such a way that equivalent geometric parts were similarly treated. He referred all forms to six classes of primitive form: *The regular tet-*

* *De Formis Crystallorum* cited in von Kobell's *Geschichte der Mineralogie.*—p. 81.

† The few measurements of crystals which had thus far been made were measurements of plane angles only, which varied with differences in development so that the interfacial angles calculated from them were often incorrect.

‡ Cristallographie, ou description der formes propres à tous les corps du règne minéral. Paris, 1783. p. 70.

rahedon, Fig. 5, and *the cube*, Fig. 6, which permit of no varieties, and *the rectangular octahedron*, Figs. 7, 8, 9; *the rhomboidal parallelopipedon* Figs. 10, 11, 12; *the rhomboidal octahedron* Figs. 13, 14, 15, and *the dodecahedron with triangular faces*, Fig. 16, all of which were susceptible of many varietions according to their angles.



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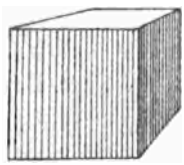

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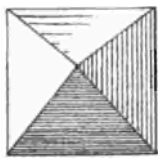

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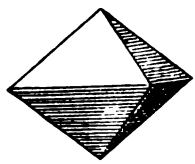

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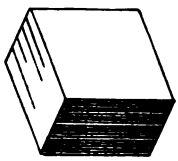

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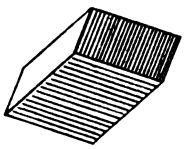

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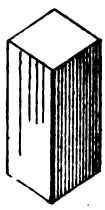

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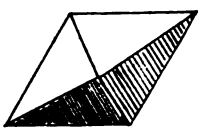

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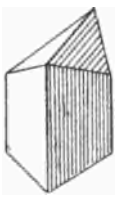

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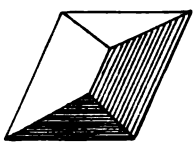

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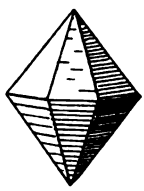

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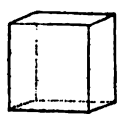
As an example of the method of derivation there could be derived from the cube, Fig. 17, Fig. 18 by truncating each edge, Fig. 19 by bevelling each edge, Fig. 20 by truncating each solid angle, Fig. 21 by replacing each solid angle by three planes, each cutting equal lengths from two edges and a different length from the third, Fig. 22 by replacing each solid angle by six planes, each cutting three unequal distances on the three edges, and many others. Similarly all the secondary forms of any compound could be derived from a primitive form, and thus connecting them in a definite series. Any series could, however, be derived from almost any member of the series in the manner described and the primitive forms could only be chosen arbitrarily.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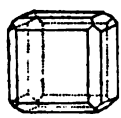
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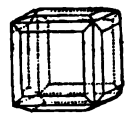
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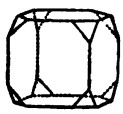
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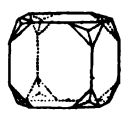
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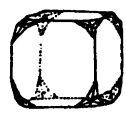
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The establishment of crystallography upon a mathematical basis is chiefly due to the ABBÉ HAÜY, who, apparently in ignorance of the discoveries of Bergman, had his attention directed to the internal structure of crystals by the accidental dropping of a six-sided prism of calcite which broke into rhombohedral fragments. He found that this property of "cleavage" was a general one and that* the crystals were built up of molecules of the shape of the cleavage forms. Although in many instances no cleavage was found or cleavage only in one direction, which yielded no solid, he assumed that such solids did exist in all crystals and were the true primitive forms upon which the other secondary forms depended and that the shape in such cases could be determined by striations and other markings on the faces or by analogy between the shapes of the secondary forms and similar forms of other crystals which did show cleavage. .

Like Delisle he made six groups of primitive forms, of which only two were identical with those of Delisle namely the tetrahedron, Fig. 5, and the dodecahedron with triangular faces, Fig. 16.

The forms, 1. PARALLEOPIPEDON. Including *cube; right prisms* with bases square, rectangular, rhombic, oblique; *oblique prisms* with bases rhombic, Fig. 28; rectangular, oblique; *rhombohedron* obtuse; acute. 2. REGULAR TETRAHEDRON. 3. OCTAHEDRON WITH TRIANGULAR FACES. Including the regular Octahedron and the octahedra with bases rectangular, square, rhombic. 4. SIX-SIDED PRISM. 5. DODECAHEDRON WITH RHOMBIC FACES. 6. DODECAHEDRON WITH TRIANGULAR FACES.

* Essai d'une theorie sur la structure des cristaux 1784. *Journal de Physique* XLIII, p. 103.

Also in Gren's *Neues Journal der Physik*, 1795, VII., p. 418.

The existence of cleavages other than those producing the primitive form led Haüy to assume the existence of still simpler shapes which he called integrant molecules. These he limited to three kinds. The tetrahedron, the trigonal prism and the parallelopipedon.

With crystals of any substance Haüy discovered that all forms other than the primitive form could be exactly imitated by building on the faces of the primitive form successive plates or layers of integrant molecules each successive layer regularly diminishing by the abstraction of one or more rows, either parallel to each edge, or to the diagonals of the faces of the primitive form, or parallel to some intermediate line. A rhombic dodecahedron might, for instance, be found to cleave with equal ease in three directions at right angles to each other. The integrant molecules would then, according to Haüy, be cubes and the kernel or prim-

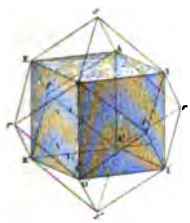

FIG. 23.

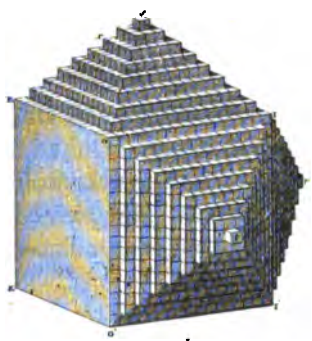

FIG. 24.

itive form also a cube, Fig. 23; then, as perfect cleavage requires that the minute integrant molecules be so piled as not to break joints, the structure would be similar to that shown in Fig. 24, in which the successive layers piled on top of any face of the cubic primitive form regularly diminish one row at a time on each edge. For only with such a rate of decretion can the pyramidal planes sOI and tOI unite to one plane sOIt and the diedral angle between alternate planes be ninety degrees. As the number of plates added would be very large and the little cubic molecules too small to be separately visible the steps would appear to lie in the planes.

Another example may be given to show that this method of building yields forms corresponding to actual crystals. Fig. 25

shows a form observed on cobaltite, in which the diedral angle at the edge, $p\,q$, is 126° 52′. Assuming a cubic kernel, Fig. 26. Fig. 27 shows the structure according to Haüy, in which the decretions

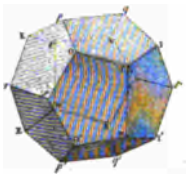

FIG. 25.

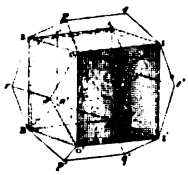

FIG. 26.

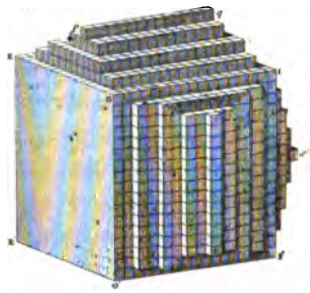

FIG. 27.

correspond to a triangle with a base of 2 and a perpendicular of 1, that is, the angle at the base has a tangent equal to 0.5, or is 26° 34′. The angle at $p\,q$ is twice the complement of this; that is, 126° 52′.

The decretion* was symmetrical that is it was repeated on all similar parts of the kernel and Haüy's experiments showed that the secondary planes usually resulted from the subtraction of one or of two rows, and were always according to some simple rational number never to his knowledge exceeding four. This is essentially the basis of the law of rational indices, the fundamental law of crystallography.

PROF. BERNHARDI, of Erfurt, pointed out† that the primitive form should be chosen, not as with Haüy, from molecules of nature, but according to convenience and fitness, and that the paralellopipedon was not a satisfactory form for calculation in many cases, as it was often an open form the height of which could only be determined from some secondary face, and he recommended the choice of closed primitive forms only and suggested seven, six of which are still regarded as the simplest forms in the crystal systems, namely: *Cube, Rhombohedron, Square Octahedron, Rhombic Octahedron, Rhomboidal Octahedron, Triple Rhomboidal*

* The law of symmetry was stated by Hauy as follows: "It consists in this, that any one method of decretion is repeated on all those parts of the nucleus of which the resemblance is such, that one can be substituted for the other by changing the position of this nucleus with respect to the eye, without it (the nucleus) ceasing to be presented in the same aspect." *Memoire sur une loi de Cristallisation*, 1815.

† Von Kobell's *Geschichte der Mineralogie*, p. 197.

Octahedron, being the seventh form was a *rectangular octahedron* which can be referred to the *rhombic octahedron*.

PROF. WEISS, of Berlin, devised a purely geometric mode of treatment in which he discarded entirely the idea of primitive form, saying* "that Haüy's hypotheses of decreted rows entangled the problem with self-created difficulties" and that the "mechanical-atomic presentation which Haüy deduced should be stripped away so that the acquired knowledge of the mathematical relation should be more clearly seen." Weiss assumed the existence of certain fundamental lines or axes passing through a common center and made four groups: 1st, with three equal axes at right angles to each other; 2d, with three axes at right angles to each other, of which two were equal; 3d, with three axes at right angles, and all different lengths; 4th, with three equal axes at sixty degrees to each other in one plane and one at right angles to these, but of different length.

He deduced all the primitive forms of Haüy by constructing planes which passed: First—Through ends of three lines. Second—Through ends of two of the lines and parallel to a third. Third—Through an end of one of the lines and parallel to two of them. By taking points along each of these lines at twice, three times and four times, etc., the original length, and constructing planes in the same way as before, he obtained all the secondary forms.

The lengths of the semi-axes of the primitive forms were called a, b and c, and the position of any face was denoted by the ratio of the intercepts in terms of a, b and c; thus, $2a : b : 3c$ or $a : 3b : 2c$, and so on. This method is still the simplest and most satisfactory if only an elementary knowledge of type forms is desired, but is cumbersome and tedious in calculation.

HAUSMANN applied spherical trigonometry to crystallographic calculations in 1803 and BERNHARDI† in 1808 pointed out that it would be better to determine trigonometrically the relations between the lines from a common point, normal to each face, as these were the directions of attraction and growth.

PROF. MOHS, of Freiberg, grouped‡ all forms in four SYSTEMS, the

* Uebersichtliche Darstellung der verschiedene Abtheilung der Krystallisations-Systeme. *Denkschrift der Berliner Akad. der Wissen.* 1814–15. p. 298.

† *Gehlen's Journal*, 1808, 2, 378.

‡ Treatise on Mineralogy, or the Natural History of the Mineral Kingdom. (Haidinger's translation), Edinburgh, 1825.

Cubic, *Pyramidal*, *Rhombohedral* and *Prismatic*, each consisting of a series of forms geometrically derived from a "fundamental form" by modifying planes which cut distances from certain lines in the ratio of whole numbers. The fundamental forms were the simplest closed forms and were not selected from cleavage or structure, but purely for geometric simplicity. In 1822 he proved the existence of two more Systems, the *Monoclinic* and *Triclinic*, the forms of which had previously been considered as partial forms of the other four systems.

F. C. NEUMANN in 1823 proposed a graphic method in which the crystal faces were indicated by the points in which radii drawn normal to the faces met the surface of a circumscribing sphere.

In 1825 WHEWELL* showed that if a solid angle of the primitive form was taken as the origin, and the edges as cordinates, with lengths x, y, z, then any secondary face would be expressed by the equation $\frac{x}{h}.\frac{y}{k}.\frac{z}{l} = m$, in which m was not dependent upon the inclination of the face, and, therefore, the quantities $\left\{\frac{1}{h}.\frac{1}{k}.\frac{1}{l}\right\}$ or say $\{p, q, r\}$ could represent the face. These are essentially the reciprocals of the Weiss intercepts, and are the indices used by Miller.

By far the most important advance since Haüy was the method developed† by PROFESSOR W. H. MILLER, of Cambridge University, in which, by spherical trigonometry, a series of simple symmetrical expressions were deduced for the normal angles in terms of the reciprocal intercepts of Whewell, and the positions of faces were indicated by stereographic projection of the points in which radii perpendicular to the faces meet the surface of the sphere. The method is still the best, and is gradually supplanting all others except for elementary work.

THE GENERAL GEOMETRIC PROPERTIES OF CRYSTALS.

A PLANE OF SYMMETRY is a plane through the centre which divides the crystal so that either half is the mirrored reflection of the other, and every line perpendicular to the plane (and within

* A general method of calculating the angles made by any planes of crystals. Rev. W. Whewell, Transactions Royal Society, 1825, CXV., 87–180.

† A treatise on Crystallography, 1839.

the solid) connects corresponding points of the solid and is bisected by the plane. Every plane of symmetry is necessarily parallel to a possible crystal face, for if two faces are symmetrical to it, it must pass through their edge, that is to be in the same zone. So, also, with a second pair of faces. But any plane lying in two known zones has rational indices (p. 281) and is a possible crystal face, as will be shown later.

One plane of symmetry may occur alone. If two planes occur they must be at right angles, and they make necessary a third at right angles to both.

AN AXIS OF SYMMETRY is a line through the centre such that a revolution of 180° or less around it will bring a face into coincidence with the original position of an equivalent face.

The intersection of two planes of symmetry is necessarily an axis of symmetry. Every axis of symmetry is either parallel to an edge between two possible faces or normal to a possible face. It has been proved* that that there can be only four kinds of axes of symmetry: *Binary*, *Ternary*, *Quaternary* and *Senary* in which equivalent faces become coincident by revolutions of 180°, 120°, 90° and 60° respectively. These may occur alone or in combinations or with planes of symmetry.

There may be distinguished three methods by which equivalent planes equally distant from the centre may be made to coincide:

1st. By reflection in a plane of symmetry.

2d. By rotation around an axis of symmetry.

3d. By composite symmetry or simultaneous rotation around an axis and reflection in a plane.

Composite symmetry can occur with a binary axis, and plane perpendicular thereto; it is impossible with a ternary axis, and with quarternary or senary axes is equivalent to simple symmetry with binary or ternary axes respectively.

AXES. The faces of crystals are defined in position by referring them to imaginary lines called axes.† The selection is largely arbitrary, but with the object of securing the simplest indices. For this purpose they must be lines parallel to the edges between possible planes and lines as important to the symmetry as possible. Generally three directions are selected which are parallel to the intersections of three occurring or possible faces.

*Groth's *Physikalische Krystallographie*, p. 313, III. edition.

†Equivalent axes are necessarily surrounded by the same number of faces placed in the same way.

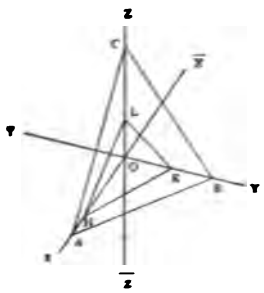

FIG. 28.

Let $X\bar{X}$ $Y\bar{Y}$ $Z\bar{Z}$, Fig. 28, be three such axes and let all distances be measured on these lines from their origin or common intersection O, distances in the direction OX, OY or OZ being regarded as positive and those in the directions $O\bar{X}$, $O\bar{Y}$ or $O\bar{Z}$ as negative.

Any plane as A B C would be determined in space by its intercepts OA, OB, OC, on these axes, or in angular position by the ratios of these intercepts, and as in crystals there is constancy in inclinations of planes to each other and therefore to the axes, but no constancy in the linear dimensions, some expression for the relative instead of the absolute values of the intercepts is used as a symbol, which may be the intercepts expressed as a proportion or some condensed expression derived from the ratios of the intercepts.

The Fundamental Law or Law of Rational Indices.

Experience teaches that a simple relation exists between the intercepts of different planes of the crystals of any chemical substance, and that *if the axial intercepts of any face be divided by the corresponding intercepts of any other face the quotients will be only simple rational numbers.*

For instance, if the intercepts of some face A B C are

$$OA : OB : OC = a : b : c,$$

then these values divided by the intercepts of any other face H K L will yield quotients

$$\frac{a}{OH} : \frac{b}{OK} : \frac{c}{OL} = h : k : l,$$

in which h, k and l are simple rational numbers such as $\frac{1}{2}$, $\frac{1}{3}$, 1,2,3.

PARAMETERS.

Some selected plane A B C is called the parametral face or unit face, and the values $a\ b\ c$, which express the simplest ratios of its intercepts, are called the parameters of the crystal.

INDICES.

It is always possible to express the ratios between h, k and l by three whole numbers because, as just stated they are simple

rational numbers, and if fractional they may always be cleared of fractions without changing the ratios, for evidently

$$h : k : l = mh : mk : ml$$

The simplest* whole numbers which express the ratios of h, k and l are called the indices of the face, and are always written in the same order, the first referring to the intercept on the axis $X\overline{X}$, the second to that on $Y\overline{Y}$, the third to that on $Z\overline{Z}$. A bar over an index, as $\overline{k}$, indicates that the intercept is negative. As indicating a face they should be written (hkl), though frequently the parenthesis is omitted; but if used as a symbol of a form they should be written $\{hkl\}$.

Indices and intercepts are inversely proportional, for from the equation (p. 276) we obtain:

$$OH = \frac{a}{h}, OK = \frac{b}{k}, OL = \frac{c}{l},$$

in which a, b and c are constant for all faces of a crystal.

If a face is parallel to an axis its intercept on that axis is infinite and its index is zero; for example, if $\frac{a}{h} = \infty$, then $h = o$ and the symbol is (okl).

The values of the intercepts OH, OK, OL, become the parametral values only when $hkl = 111$. For with these values only can we obtain:

$$OH = \frac{a}{h} = a, \quad OK = \frac{b}{k} = b, \quad OL = \frac{c}{l} = c.$$

Determination of the Elements of a Crystal.

The three axial planes and the "parametral face" constitute the *elementary planes*. These are chosen to yield the simplest indices and are usually planes of cleavage, or twinning or gliding planes, and are preferably planes of symmetry.

In the most general case there are five undetermined elements, namely:

The angles between the axes, Y Z or a, X Z or β, X Y or γ.

The ratio between the parameters a, b, c, in which $b = 1$.

* Experience shows that the faces which most frequently occur will, with proper selection of the parametral plane, have as indices 0 or 1 or rarely 2.

1° *Determination of the angles between the axes.*

These may be determined most simply from the measured angles between the axial planes, as follows:

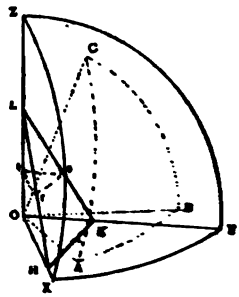

Fig. 29.

Let the surface of a sphere, described around O, the centre of the crystal, meet the axes in X, Y and Z, Fig. 29.

Construct A B C the polar triangle of X Y Z, then will A be the pole of the axial plane YOZ, B the pole of XOZ, and C the pole of XOY.

The sides of A B C therefore measure the normal angles between the axial planes, that is between the planes (010), (100), (001) and these angles are determined by measurement

$$A\,B = (100)-(010),\quad B\,C = (010)-(001),\quad A\,C = (100)-(001).$$

The angles of the triangle can therefore be calculated by formula

for instance: $$\cos C\,A\,B = \frac{\cos B\,C - \cos A\,B \cos A\,C}{\sin A\,B \sin A\,C}$$

Since A B C and X Y Z are polar triangles

$$\alpha = Y\,Z = 180^\circ - C\,A\,B,\quad \beta = X\,Z = 180^\circ - C\,B\,A,$$
$$\gamma = X\,Y = 180^\circ - A\,C\,B.$$

The angles between the axes are therefore determined.

Example. In Axinite by measurement it is found that

		log. cos.	log. sin.
A B or (100—010)	$= 48^\circ\ 21'\ 8''$ whence	9.82253	9.873465
B C or (010—001)	$= 97^\circ\ 50'\ 8''$ "	9.13459	9.99593
A C or (100—001)	$= 93^\circ\ 48'\ 56''$ "	8.82311	9.99904

$$l \cos C\,A\,B = 9.09181$$
$$C\,A\,B = 82^\circ\ 54'\ 13'' \text{ or } 97^\circ\ 5'\ 47''$$
$$\alpha = 97^\circ\ 5'\ 47'' \text{ or } 82^\circ\ 54'\ 13''$$

Similarly β and γ can be determined

2° *Determination of the parameter ratios.*

In Fig. 29 let HKL be any plane cutting the three axes and with known indices *hkl*.

The spherical triangle *rst* described from L as a centre can be solved because its angles are

t=(100—(010) s= (100)— (*hkl*) and r= (010) — (*hkl*), all of which may be measured.

The sides, *tr* and *ts*, may be calculated by formula, for instance:

$$\cos tr = \frac{\cos s + \cos t \cos r}{\sin t \sin r}.$$

These sides measure angles in the plane triangles H O L and K O L, respectively, and in each of these one other angle has already been determined. The triangles may, therefore, be solved for the *relative* lengths of their sides—that is, for the intercepts of the plane.

For instance, in K O L, the angle at L is measured by *ts*, and the angle at O by Y Z or a, hence the angle at K is 180°—(a+*ts*), and the sides are given by the formula,

$$\text{O L} : \text{O K} = \sin (180° - a - ts) : \sin ts$$

Similarly,

$$\text{O L} : \text{O H} = \sin (180° - \beta - tr) : \sin tr$$

EXAMPLE:

Given t=100° 41′, s=59° 10′, r=76° 33′, a=82°21′, β=73° 11′. Required a, b and c.

$$\cos tr = \frac{\cos s + \cos t \cos r}{\sin t \sin r} = \frac{.5125 + .1854 \times .2335}{.98215 \times .9726} = .5819,$$

$$tr = 54° 35'.$$

$$\cos ts = \frac{\cos r + \cos t \cos s}{\sin t \sin s} = \frac{.2335 + .1854 \times .5125}{.98215 \times .8587} = .3895$$

$$ts = 67° 5'.$$

In triangle K O L O L: O K=sin (180° —82° 21′ —67° 5′): sin 67° 5′,=sin 30° 34′ : sin 67° 5′=0.5085 : .9205=.5525 : 1.

In triangle H O L O L : O H=sin (180°—73° 11′—54° 35′): sin 54°35′=sin 52° 14′ : sin 54° 35′=0.7905 : .8150=.5525 : .5696 Hence O H : O K : O L=.5696 : 1 : .5525= a : b : c.

SPHERICAL PROJECTION.

Imagine a sphere described around the centre of a crystal with any radius and radii drawn normal to each face.

The point in which the radius normal to any crystal face meets the surface of the sphere, is called the *pole* of the face, and is denoted by the symbol of the face.

Planes which intersect in parallel edges will evidently have their normals in one plane and their poles in the circle which it cuts from the sphere of projection. Such a series of planes constitute a *Zone*, the plane of the normals is the *Zone Plane*, the circle is the *Zone Circle*, and the line through the centre parallel to the face and edges of the zone is the *Zone Axis*.

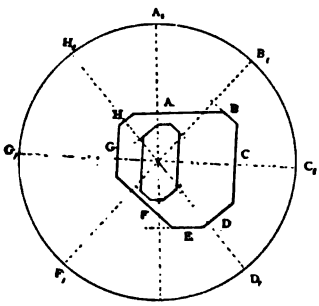

FIG. 30.

Fig. 30 represents the section made by a zone plane, the normals to the faces A, B, C, etc., meet the zone circle in the poles A_1, B_1, C_1, etc.

The same radii are evidently normal to the crystal faces of the enclosed ideal form in which equivalent faces are equally distant from the centre. Hence the poles on the surface of the sphere, in their arrangement will reveal the hidden regularity of unequally developed crystals.

Fig. 30 shows, also, that the arc of the zone circle between any two poles measures the normal angles, the supplements of the angles between the corresponding faces. Different intersecting zone circles give spherical triangles, the sides of which are normal angles, which can be solved by simple formulæ, provided certain parts have been determined by measurement or previous calculation.

A number of simple relations between the faces in zones have been deduced by means of which it is possible to greatly reduce the number of necessary direct measurements and to simplify the calculations.

SYMBOL FOR A ZONE AXIS.

The direction of intersection* of two crystal faces (hkl) and $(h'k'l')$ is $[uvw]$ in which $u = kl' - lk'$, $v = lh' - hl'$, $w = hk' - kh'$.

These values may be obtained by cross multiplication of the twice written indices, striking off end terms and reading down alternately from left to right and from right to left, thus:

* Miller's *Treatise on Crystallography*, p. 7.

$$\begin{array}{c|cccccc|c} h & k & & l & h & & k & l \\ & & \times & & & \times & & \\ h' & k' & & l' & h' & & k' & l' \end{array}$$

As all the terms are whole numbers the values of u, v and w will be also. A zone is designated by this symbol [uvw] or by the symbols of two of its planes [*hkl*, *pqr*], or by letters designating the faces [P, Q], always enclosing with the parallel bars.

EQUATION FOR ZONE CONTROL OR CONDITION THAT A FACE MAY BELONG TO A ZONE.

If a face (*pqr*) lies in a zone [uvw] its indices must satisfy* the equation $pu + qv + wr = 0$.

If two indices of a face are known, and the zone is known, the third index may therefore sometimes be found.

Example. By test with a reflection goniometer the face ($3k1$) is found to be in the zone $[1\bar{1}\bar{1}]$; substituting in the above equation $3\times1+k\times\bar{1}+\bar{1}\times1=0$ whence $3-k-1=0$ and $k=2$.

FACE IN TWO ZONES.

The indices of a face† which lies in the zones [uvw] and [u'v'w'] will be $h = uv' - vu'$, $k = vw' - wv'$, $l = wu' - uw'$.

These values may be obtained by cross multiplication.

Example.—By test a face (hkl) is found to lie in the zones $[2\bar{1}0]$ and $[01\bar{2}]$, required the values of h, k and l.

$$\begin{array}{c|cccccc|c} 2 & \bar{1} & & 0 & 2 & & \bar{1} & 0 \\ & & \times & & & \times & & \\ 0 & 1 & & \bar{2} & 0 & & 1 & \bar{2} \end{array} \qquad h = 2-0,\ k = 0+4,\ l = 2-0,$$

that is, $(h\,k\,l) = (242) = (121)$.

TO FIND A FOURTH FACE IN A ZONE.‡

Let $A = (efg)$, $B = (hkl)$ and $C = (pqr)$ be known faces of a zone, the poles of which lie in the order named.

To find the position of any fourth face, $D = (mno)$, if its indices are known.

$$\frac{AC}{CD}(\cot AC - \cot AD) = \frac{AB}{BD}(\cot AB - \cot AD).$$

* Ibid p. 10.

† Ibid, p. 8.

‡ Groth's *Physikalische Krystallographie*, III. ed., p. 584.

The values of $\frac{AC}{CD}$ and $\frac{AB}{BD}$ are such as result by cross multiplication of pairs of corresponding indices:

$$\frac{AC}{CD}=\begin{matrix}e & f\\ \times & \\ p & q\\ p & q\\ \times & \\ m & n\end{matrix}=\frac{eq-fp}{pn-qm};\ or\ \begin{matrix}f & g\\ \times & \\ q & r\\ q & r\\ \times & \\ n & o\end{matrix}=\frac{fr-gq}{qo-rn};$$

$$or\ \begin{matrix}e & g\\ \times & \\ p & r\\ p & r\\ \times & \\ m & o\end{matrix}=\frac{er-gp}{po-rm}$$

$$\frac{AB}{BD}=\begin{matrix}e & f\\ \times & \\ h & k\\ h & k\\ \times & \\ m & n\end{matrix}=\frac{ek-fh}{hn-km};\ or\ \begin{matrix}f & g\\ \times & \\ k & l\\ k & l\\ \times & \\ n & o\end{matrix}=\frac{fl-gk}{ko-ln};$$

$$or\ \begin{matrix}e & g\\ \times & \\ h & l\\ h & l\\ \times & \\ m & o\end{matrix}=\frac{el-gh}{ho-lm}$$

Very frequently two of the three identical ratios are indeterminate.

EXAMPLE.

In a crystal of pyroxene, given: A = (*efg*) = (100), B = (*hkl*) = (101), C = (*pqr*) = (001), D = (*mno*) = ($\bar{3}$01)., A B = 49° 39′, A C = 73° 59′. Required A D.

By trial the first and third ratios are found to be indeterminate, but from the third we obtain

$$\frac{AC}{CD}=\frac{1.1-0.0}{0.1-1.3}=\frac{1}{3};\ \frac{AB}{BD}=\frac{1.1-0.1}{1.1-1.3}=\frac{1}{4}$$

substituting in the equation

$$\frac{1}{3}(\cot 73^\circ\ 59'-\cot AD)=\frac{1}{4}(\cot 49^\circ\ 39'-\cot AD)$$

$$1.1504-4\cot AD=2.5487-3\cot AD.\ \cot AD=1.3983$$

$$AD=144^\circ\ 26'$$

ZONE OF TWO PINACOIDS.

Every face in the zone will have that index zero which is zero in both pinacoids. For example if a face lies in the zone of [100, 010] its third index must be zero for the zone symbol is [001] p. 280 and $h.0 + k.0 + l.1 = 0$ can be true only if $l = 0$.

ZONE THROUGH ONE PINACOID.

The ratio of the two indices which are zero for the pinacoid, is constant for all faces of the zone. For example the symbol of the zone [100, hkl] is [$0l\bar{k}$]. Any third face (pqr) must satisfy the equation $p0 + q\,l - r\,k = 0$, that is $ql = rk$ or $\frac{k}{l} = \frac{q}{r}$

ZONES IN WHICH TWO INDICES ARE CONSTANT.

If two faces have two corresponding indices in each with the same ratio, all faces in their zone will have those two indices in that ratio. For example, the symbol of the zone of the faces (123) and ($2\bar{4}5$) is [$\bar{2}10$] A face (hkl) to be in this zone must satisfy the equation $-2h + k + 0\,l = 0$, that is $2h = k$.

CHANGING AXES.*

If three edges are preferred to those originally selected as axes directions proceed as follows:

From the original indices of the *new* axial planes determine the symbols of their intersections (that is, their zone symbols), [uvw], [$u_1v_1w_1$] [$u_2v_2w_2$].

Then, if the indices of any face referred to the old axes is (hkl), its new indices h_1, k_1 and l_1 will have the following values:

$$h_1 = hu + hv + hw$$
$$k_1 = ku_1 + kv_1 + kw_1$$
$$l_1 = lu_2 + lv_2 + lw_2.$$

CHANGING PARAMETERS.

hkl the indices of a face referred to parameters a, b, c,
$h_1k_1l_1$ " " "the " " " " a_1, b_1, c_1,

$\frac{a_1}{h_1} = \frac{a}{h}$, $\frac{b_1}{k_1} = \frac{b}{k}$, $\frac{c_1}{l_1} = \frac{c}{l}$ then if this face is chosen as the parametral plane $a_1 = \frac{a}{h}$, $b_1 = \frac{b}{k}$, $c_1 = \frac{c}{l}$ and any other face, the indices

* Miller *Treatise on Crystallography*, p. 17.

of which were pqr, will receive new indices $p_1q_1r_1$, in which

$$p_1 = \frac{pa_1}{a}, \quad q_1 = \frac{qb_1}{b}, \quad r_1 = \frac{rc_1}{c}.$$

Stereographic Projection.

The sphere containing the poles of the crystal faces is most conveniently represented in Stereographic Projection.

Some important plane through the centre of the sphere is selected as a plane of projection, and all poles of the sphere are projected in this plane and fall within the limits of the so-called "Primitive circle."

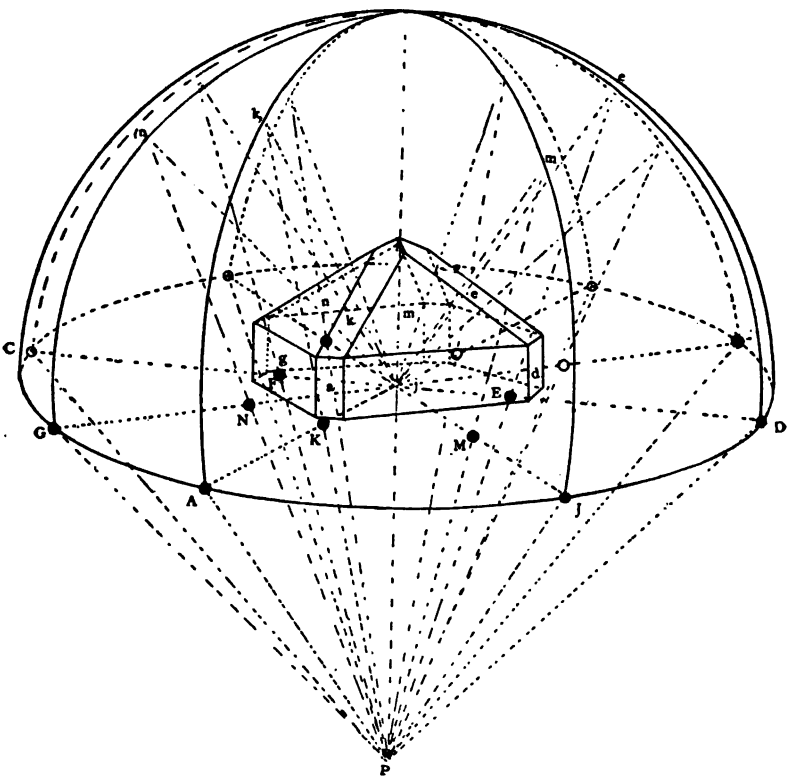

Fig. 31.

For instance, let Fig. 31 represent the upper half of a crystal of cassiterite within a sphere of projection. The crystal faces a, d, g, k, m., etc., will have their poles in the points A, D, G, k_1, m_1, etc., where the normal radii intersect the spherical surface.

Let the equatorial plane be the plane of projection, let the south pole be the point of sight, then if lines are drawn from the south pole to the various poles in the northern hemisphere, they will all pierce the equatorial plane at points A, D, G, K, M, etc., in the primitive circle which are the projections of the poles.

PRINCIPAL CHARACTERISTICS OF STEREOGRAPHIC PROJECTION.

1° All zone circles at right angles to the primitive circle are projected as diameters, all others, as arcs of circles,* cutting the primitive circle in the extremities of a diameter.

2° *If the pole (F. Fig. 33) of a zone circle CPC$_1$ is united with the poles of two faces (P and Q) of the zone by straight lines, and these prolonged to the circumference, they cut from it an arc equal to the normal angle between the two faces.*†

Free-hand construction in many instances serves to give a comprehensive view of the symmetry and relations of the faces and zones. For accurate construction a few rules are needed, which are based upon characteristics 1 and 2.

PROBLEM 1.

Given the projection of a zone circle, to find that of its pole.‡

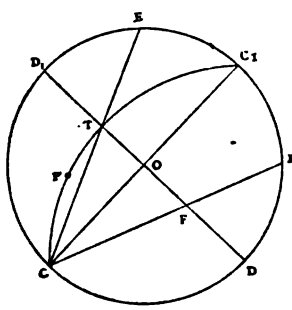

FIG. 32.

In Fig. 32. Given C P C$_1$ to find F.

C P C$_1$ intersects the primitive circle in the diameter C C$_1$. Its pole must lie on that circle which is projected as the diameter D D$_1$ normal to C C$_1$ and at 90° from the point T where the two circles intersect. Draw C E through T, lay off E E$_1$ = 90°, draw E$_1$C, then is F the required pole because it is a point on D D$_1$ and by the second characteristic it lies at a quadrants distance from T.

PROBLEM 2.

Given the projection of the pole of a great circle to draw the circle.

In Fig. 32 given F to find C P C$_1$.

Draw a diameter D D$_1$ through F and another C C$_1$ normal to this. Through F draw C E$_1$, make E E$_1$ 90°, draw E C, then are

* For demonstration, Story-Maskelyne's Crystallography, p. 30.

† Ibid, p. 33.

‡ Miller's *Treatise on Crystallography*, p. 133.

T, C and C_1, three points of the zone desired. Through these pass the arc of a circle.

PROBLEM 3.

In any zone given the angle between two faces and the projection of one of them to find that of the other.

In Fig. 33, given the zone CPC_1, the face P, and the angle P to $Q = a$. To find Q,

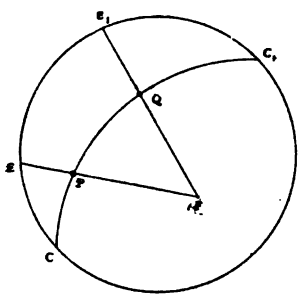

FIG. 33.

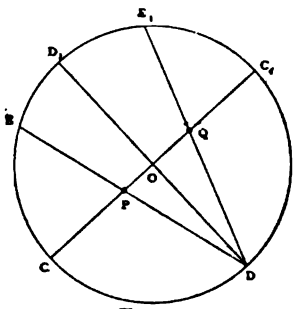

FIG. 34.

Find F the pole of the zone $C\,P\,C_1$, as in problem 1. Draw F E through P, make E E_1 equal a, and draw E_1 F. Then by the second characteristic, Q is the desired projection.

In Fig 34, is represented the special case in which the given zone $C\,P\,C_1$ is normal to the primitive circle. In this case the pole of the zone falls at D, the extremity of the diameter normal to $C\,C_1$.

If $a = 180°$, the second face will lie outside the primitive circle. The construction is not changed.

PROBLEM 4.

*Given the projections of two faces in a zone to find the projection of the zone circle.**

In Fig. 35, given P and Q to find $C\,P\,C_1$.

Draw a diameter through P. The face P_1 opposite P, will be on it.

Draw O A perpendicular to this diameter, draw P A, and from A, a line perpendicular to P A. The intersection of this perpendicular with the diameter through P, will be P_1; the projection of the pole of a face opposite P, that is 180° from P, in the same zone.

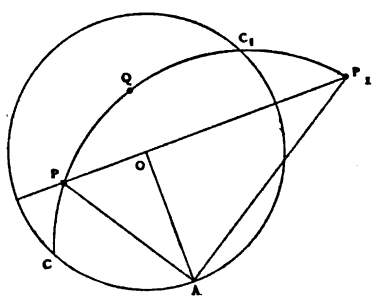

FIG. 35.

*Miller's *Treatise on Crystallography*, p. 133.

The arc of a circle through the three points, P, Q and P_1, will be the desired circle.

EXAMPLES. Application of preceding constructions to the projection (Fig. 36) of the cassiterite crystal (Fig. 31).

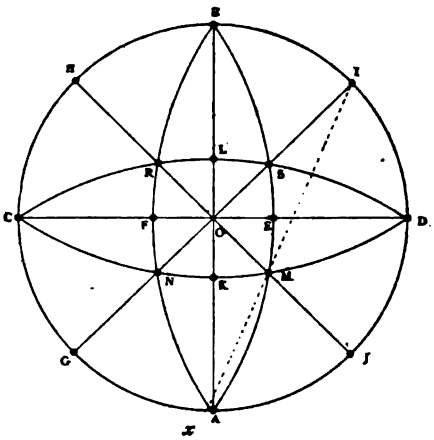

FIG. 36.

The poles lying in the primitive circle are separated by arcs equal to the true normal angles. The poles of all other faces in this instance lie in zone circles normal to the primitive circle, therefore projected as diameters. The true position of any one of these is found by Problem 3. For example: M — J or (110) — (111) = 46° 27′. Lay off J x = 46° 27′, draw x I to the pole I

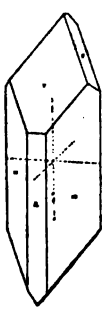

FIG. 37.

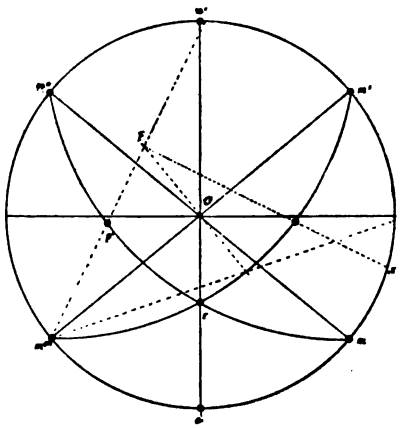

FIG. 38.

of the circle J H cutting the latter at M, the required projection. The pole R is in the zone of M and J, and being an equivalent face O R = O M.

Draw zone circles through C M D, B M A, C R D and B R A.

The poles of N and S will lie at the intersections as shown. For the second order forms K lies in the zone [A B] and in the zone [M N], hence is at K. Similarly the faces *e*, *l* and *f* have poles E, L and F.

A crystal of barium chlorate shown in Fig. 37 yields the projection Fig. 38. The plane of projection is taken normal to the zone [m, a].

Given $m - a = 48° 53\frac{1}{2}'$, $m - r = 41° 51\frac{1}{2}'$, $'m - p = 56° 39'$ In Fig. 37 lay off arcs equal $48° 53\frac{1}{2}'$ each side of *a* and *a'* determining *m*, *m'*, *m''*, *m'''*. Lay off an angle equal $41° 51\frac{1}{2}'$ and draw a line (not shown) to pole of the zone [*a a'*], intersecting the latter at *r*. By trial *p* lies in the zone [*m''' r*], construct this zone circle, find its pole, F by Problem. Lay off $m' s = 56° 39'$, draw *s* F, then, by Problem 3, *p* is the desired pole; *p'* is in the zone [*m r*] symmetrical to p.

DEVEREUX PRIZE.

A prize of one hundred dollars has been offered by Mr. W. B. Devereux (S. of M. '78) to graduates of the School of Mines for the best memoir on the electric transmission of power for mining purposes. The memoir should describe in detail, with the necessary drawings, an existing plant or plants with the practical results obtained therefrom, giving, if possible, the itemized cost of installation and working. Preference will be given to memoirs describing plants with which the writer has had personal connection, either in the design, the construction or the operation of the same.

Memoirs must be handed in to the Dean of the faculty on or before December 1, 1897.

ABSTRACTS.

METALLURGY FOR 1896.

By Joseph Struthers, Ph.D.

The following list of note references is composed of the more important articles on general metallurgical practice:

Abbreviations Employed.

Amer. = American.	Mag. = Magazine.
Can. = Canadian.	Manuf. = Manufacturer.
Chem. = Chemical.	Mech. = Mechanical.
Col. = Colliery.	Min. = Mining.
Eng. = Engineering.	Sci. = Scientific.
Frank. = Franklin.	Soc. = Society.
Guard. = Guardian.	Trans. = Transactions.
Journ. = Journal.	

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LEAD.

The Lead Industry of the United States.—E. A. Caswell. (General review.)—*Iron Age*, January 2d, '96.

Methods for the Collection of Metallurgic Dust and Fume.—M. W. Iles.—SCH. OF MINES QUAR., January, '96.

Special Device for the Elevation of Slag.—*Eng. and Min. Jour.*, January 18th, '96.

Note on the Handling of Slags and Mattes at Smelting Works in the Western United States.—Wm. Braden. (Illustrated descriptive.)—*Trans. Amer. Inst. Min. Engrs.*, February, '96.

A modern Silver-Lead Smelting Plant.—L. S. Austin.—*Trans. Amer. Inst. Min. Engrs.*, September, '96.

COPPER.

The Copper Industry of the United States.—James Douglas. (Early history and subsequent development.)—*Iron Age*, January 2d, '96.

Cost of Copper Production. (Editorial.)—*Eng. and Min. Jour.*, January 11th, '96.

Matte Smelting.—W. L. Austin.—*Min. and Sci. Press*, March 28th, '96.

Bessemerizing Nickel Matte.—H. W. Edwards.—*Eng. and Min. Jour.*, May 2d, '96.

Matte Smelting in California.—Herbert Lang. (Description of Keswick Works, California.)—*Eng. and Min. Jour.*, July 25th, '96.

Anaconda Electrolytic Copper Refinery. (Ill.)—*Eng. and Min. Jour.* September 19th, '96.

A Hot Blast System for Copper Matting and Silver Lead Furnace.—J. W. Nesmith.—*Min. and Sci. Press*, October 17th, '96.

SILVER.

The Effect of Washing with Water upon the Silver Chloride on Roasted Ore. (Discussion by L. D. Godshall on paper of W. S. Morse.)—*Trans. Amer. Inst. Min. Engrs.*, February, '96.

The Lixiviation of Silver Ores.—John H. Clemes. (A paper read before the Institute of Civil Engineers.)—*Industries and Iron*, March 20th, '96.

The Volatilization of Silver in Chloridizing Roasting.—L. D. Godshall.—*Trans. Amer. Inst. Min. Engrs.*, April, '96; *Eng. and Min. Journ.*, May 16th, '96.

The Sulphuric Acid Process of Treating Lixiviation Sulphides.—Fred. P. Dewey. (The Dewey-Walters Process.)—*Trans. Amer. Inst. Min. Engrs.*, July, '96.

The Gates Canvas Plant.—W. S. Hutchinson. (Description of Kennedy Plant, California; applicable to any mill tails.)—*Min. and Sci. Press*, October 1st, '96.

GOLD.

Notes on the Treatment of Tailings by the Cyanide Process at the Standard Consolidated Mines at Bodie, California.—T. H. Leggett.—*Eng. and Min. Journ.*, January 4th, '96.

Ore Treatment, Cyanide and Chlorination.—W. P. Harvey.—*Min. and Sci. Press*, January 11th, '96.

The Amalgamation of Rich Free Gold Ores.—F. Hille.—*Eng. and Min. Journ.*, February 7th, '96.

The Accumulation of Amalgam on Copper Plates.—R. T. Bayliss.—*Trans. Amer. Inst. Min. Engrs.*, February, '96.

The Accumulation of Amalgam in Copper Plates. (Discussion of paper by R. L. Baylis, presented at the Pittsburg meeting, February, 1896.)—*Trans. Amer. Inst. Min. Engrs.*, July, '96.

Notes on the Hydro-Metallurgy of Gold and Silver.—W. G. Waring.—*Eng. and Min. Journ.*, May 9th, '96.

The Cassel-Hinman Gold and Bromine Process.—P. C. McIlhiney.—*Journ. Amer. Chem. Soc.*, May, '96.

The Cyanide Process at the Mercur Mine.—B. E. Janes.—*Min. and Sci. Press*, May 23d, '96.

Recent Improvements in Gold Milling.—H. M. Chace.—*Eng. Mag.*, June, '96.

Are the Cyanide Patents Invalid?—J. S. C. Wells.—*Eng. Mag.*, August, '96.

The Engelhardt Bromine Gold Extraction Process in Operation.—D. C. Pret and H. Taschler.—*Eng. and Min. Journ.*, September 26th, '96.

Laboratory Tests in Connection with the Extraction of Gold from Ores by the Cyanide Process.—H. Van F. Furman.—*Trans. Amer. Inst. Min. Engrs.*, September, '96.

The Cyanide Process in the United States.—Geo. A. Packard.—*Trans. Amer. Inst. Min. Engrs.*, September, '96.

The Cyanide Process at the Utica Mine.—Thos. N. Smith.—*Min. and Sci. Press*, October 1st, '96.

Metallurgy of Gold.—H. V. Furman.—*Col. Eng.*, October, '96.

Improvements in Gold Extraction.—H. Livingston Sulman. (Cyanide process and leaching slimes.) *Inst. of Mining and Met., London*, Vol. III, part 2, '96.

Some Experiments with Brom-Cyan.—H. C. Cutter.—*Engineer's Year Book*, Minn. Univ, '96.

ALUMINUM.

Notes on the electro-crucible fusion of Steel and Iron. B. H. Thwaite. *Iron and Coal Trades Rev.*, January 31st, '96.

The Manufacture of Aluminum by Electrolysis and the Plant at Niagara for its extraction.—A. E. Hunt. (Description of paper read before the Institute of Civil Engineers.) *Col. Guard.*, February 14th, '96.

The Aluminum Industry.—Orrin E. Dunlop.—*Min. and Sci. Press*, February 15th, '96.

The History of Electric Heating Applied to Metallurgy.—F. P. Dewey.—*Jour. Amer. Chem. Soc.*, March, also *Elec. Rev.*, March 25th, '96.

The British Aluminum Works at Fayers. (Ill. descriptive.)—*Elec. Engr. Lond.*, April 24th, '96.

Electro-Metallurgy of Aluminum.—Jos. W. Richards. (Ill.)—*Jour. Franklin Inst.*, May, '96.

MERCURY AND TIN.

Treatment of Quicksand Ores in the Asturias, Spain.—*Eng. and Min-Jour.*, August 15th, '96.

Tin Smelting at Pulo Brani, Singapore.—Jno. McKillop and T. Flower Ellis. (A paper read before the Institute of Civil Engineers.)—*Indus. tries and Iron*, March 20th, '96.

BOOK REVIEWS.

The Mechanical Engineering of Power Plants. By FREDERICK REMSEN HUTTON, E. M., Ph. D., Professor of Mechanical Engineering in the School of Engineering of Columbia University. New York, John Wiley & Sons. London, Chapman & Hall, Limited. 1897. Price, $5.00.

Professor Hutton has given us a book upon lines which, while by no means new to those who have had the opportunity of meeting the practical conditions of power plants in actual operation, are until now untreated in technical literature. The orthodox text-book treats of the dynamical side of engineering as if that were the only one in existence, leaving the student to find out by experience that there were more things in heaven and earth than were dreamed of in his limited philosophy, while here we have clearly discussed at least some of the things which the other books carefully leave out. Usually students are taught how things are made, but not how they are used, how they are tested and examined, but not how they are run. The author of this book tells us that it is his wish to place all students of engineering in the same position as those who are fortunate to have had previous experience in the shop or power-house, and so far as this can be done by a book the present volume accomplishes that most desirable result. While there are many things which can only be learned in the hard school of practical experience, every work which gives us the records of the experience of others goes a long way towards reducing the difficulties of the application of theory to practice.

After a brief introduction, analyzing and classifying the various portions of a power plant, there follows a very complete series of chapters descriptive of all kinds of steam engines, with an examination of details, including the practice of the leading builders all over the country. This is followed by the second part, treating of boilers, boiler settings, furnaces, accessories, care and management, inspection and testing.

It is to be noted that there are many points discussed for which one may look in vain in text-book literature, and yet which are those with which the young engineer is most likely to be called on to cope. The advantages of the horizontal cylinder, as compared with the vertical arrangement; the conditions favoring the beam mechanism; the advantages of the independent air-pump operated at different piston speeds from those of the main engine; the different methods of effecting condensation—all these are questions which do not lend themselves to purely rational or transcendental treatment, and yet which rest on principles of which a sound training should take account.

Former students of the author (the last paragraph of the thoughtful preface will be of special interest to such) are likely to recognize a feature of the several chapters on which their lecture-room courses used to lay special emphasis, and which is of signal value to others as well. It is the grouping in concise and yet clear terms of the advantages and disadvantages of a principle or a method or a design. This should be of service to young practitioners and others in determining their attitude as respects selection of type or construction for given conditions. The author rarely dogmatizes on these matters, but in a singularly impartial and judicial manner states both sides of the case and leaves the question to be decided on its merits. This is notably manifest in the discussion of the rotary steam engine; of the compound type of engine; of the throttling and automatic cut-off method of governing, and with respect to the sectional principle in boiler construction..

Another set of most significant and original chapters are those on engine foundations and the piping and accessories to the steam supply and the setting of boilers. These scarcely admit of a mathematical treatment, nor do they justify a purely descriptive one. What is needed is a critical and analytical survey and discussion, such as they receive at the author's hands. The discussion on vibration of engines is particularly sound. The chapter on valve gears is specially lucid, and another important one is that on general boiler construction.

The chapter on the boiler furnace as the origin of power is especially to be noted as a most clear and satisfactory presentation of an important subject, and the closing general remarks contain some excellent common-sense suggestions on points often overlooked.

In the appendix is found an interesting historical summary of the development of power plants from Hero's Elopile to the modern multiple expansion engine, and includes many new determining steps in the growth of the power plant. Here also are given numerous notes and references as authority for the statements made in the text.

These notes are intended as the author says to serve as open doors into the broader field of detailed professional study, upon such questions as naturally come up as subjects of papers before engineering societies. It is interesting to observe that the Transactions of the American Society of Mechanical Engineers and Kent's Mechanical Engineers' Pocket Book are the references which occur most often.

Altogether the book is a valuable contribution to a branch of mechanical engineering hitherto treated in a very different manner, and it may rightly be welcomed to the library of both student and professional engineer. H. H. S.

The Materials of Construction. A Treatise for Engineers on the Strength of Engineering Material. By J. B. JOHNSON, C. E., Professor of Civil Engineering, Washington University, St. Louis, Mo. John Wiley & Sons, New York. 1897. 787 pages; tables, plates, diagrams, illustrations. Price, $6.00.

The book is devoted almost entirely to the *testing* of materials, and is a compilation of work done by the best modern experimenters on this subject. The various kinds of tests are discussed in a careful manner and appropriate formulæ given for use in computing the results.

Characteristic tests of the different materials are given, which are interesting for purposes of study. These are gathered from many sources, but principally from the publications of Bauschinger, Tetmajer and U. S. Government. They are given mostly in the form of stress-diagrams. This is a distinct feature of the book, and is to be thoroughly commended. In no way can the results of a test be so satisfactorily shown as by a plotted curve. It enables distinctions to be made which would be wholly lost in a mere tabulation of figures.

The author wisely drops the use of the word *strain*, which is always a source of confusion to students. On the other hand he introduces a new term, first used by the French Commission, "*apparent elastic limit*" as a substitute for "*yield-point*" or "*breaking-down point*," which have been standard expressions among engineers for years. The author also gives an empirical method for determining the position of this point on a diagram. It is questionable whether the profession will take kindly to these innovations.

The chapters on Resilience, Manufacture and Testing of Paving Brick and Micrographic Analysis of Iron and Steel are all valuable, and out of the ordinary in books of this class. One would suppose from the article, however, that the use of the microscope as a practical test instrument to determine the quality of iron or steel was confined to foreign countries, whereas most excellent work in this line is being done as a daily routine in some of our largest steel works.

The chapters on the manufacture of iron and steel seem also to be largely taken from English text-books; at least the best American practice is not given. This is particularly true of the chapter on steel, in which several of the statements regarding important points in the process of manufacture are quite at variance with what our steel makers consider the best practice. The illustrations of steel converters are all old types; none of the new types are given.

The chapters on timber, its varieties and strength are taken from the Bulletins of the Forestry Division of the United States Agricultural Department, and from Reports of the Watertown Arsenal. They contain much useful information, though as a book of reference for engineers its value would have been greatly increased if results of tests from other reliable investigators had been given, particularly the work of such men as Professors Lanza and Bovey.

Indeed we are surprised that such slight mention is made of the very

excellent work done by Prof. Lanza, who is a recognized authority upon this subject by the best engineers of the country.

Printing in the appendix the proposed standard specifications for testing is a good idea and will prove quite useful to students for reference.

The book contains a large amount of valuable information, the data given being much more up-to-date and useful than that contained in most other books of its class now upon the market.

The illustrations used throughout the book are as a whole very poorly printed, and some of them are inexcusably bad. The proof-reading was also carelessly done; many mistakes are noticeable. I. H. W.

The Theory of Solution and its Results. By J. LIVINGSTON R. MORGAN, Ph. D. John Wiley & Sons, New York. 1897. 63 pages.

This book is intended as an introduction to the study of the theory of solution and electrolytic dissociation. It is divided into the following chapters: Theory of Solution, Determination of Electrolytic Dissociation, Theory of the Voltaic Cell, and Analytical Chemistry from the Standpoint of Electrolytic Dissociation.

Many chemists who have not had leisure to keep informed on the development of chemical theory from a mathematical standpoint will welcome this book as giving in a concise form a résumé of the work of Ostwald, Nernst and Kohlrausch. E. H. M.

Tables Showing Loss of Head due to Friction of Water in Pipes. By EDMUND B. WESTON, C. E. Van Nostrand & Co 1896. Flexible covers; 171 pages.

The water-works engineer, in common with his professional brethren in all other lines where experience and knowledge have to be applied to cases where judgment determines an aggregate first cost of considerable extent, is, perhaps, more troubled to decide on a wise diameter of water mains than in almost any other detail of his professional work. If the friction in the pipe is wrongly calculated by over-estimating it, a diameter will be chosen which increases the original outlay considerably beyond what it would be if a smaller value had been chosen for the friction, but as time goes on and the pipes roughen by oxidization and other causes, and the mains are also taxed by the growth of the population and the consequent consumption of water, the reputation of the engineer suffers, and he can never explain the motive of his original economy.

Mr. Weston's book aims to divide the conditions for the flow of water in the pipes, as derived from experiment, into three great classes. He includes in his first class the experiments with smooth or drawn pipes, such as will have a surface resembling lead or brass. His second class is new cast-iron pipes, and his third is old cast-iron pipes whose interior surfaces have become roughened by use and oxidization. The formula which he derives for smooth pipes is used in computing his Table No. 1, which is the result of 238 experiments made with 27 different pipes with smooth interiors and the sizes ranging from ½ to 3 inches. He adds a supplementary table of theoretical velocity as the projection of his curve outside of experiments for results beyond the highest limits of his first table. The tables give the mean velocity in feet per second with head required to produce this velocity; the discharge in gallons per minute; the loss of head in feet for each 100 feet caused by friction per twenty-

four hours and a rebate for loss of head due to orifice of influx. Mr. Weston's formula was published in the Transactions of the A. S. C. E., Vol. XXII., 1890. The application of his tables is given in a series of practical examples.

In the second group is a series of tables giving the same data for pipes increasing by the usual intervals from four to sixty inches in diameter and is calculated by the formulæ of H. Darcy which are given in his work, Recherches Experimentales Relatives au Mouvement de L'eau dans les Tuyaux. These formulæ which were originally expressed in French measures are reduced to their English equivalents and are given in their two forms with their velocity of flow less than 0.33 feet per second and for velocities exceeding that limit. There is also a supplementary table, as in the first case, carrying the curve of theoretical velocities beyond the highest limits of the second table and, as before, examples of the practical application of the formulæ and tables follow.

The loss of head due to friction in pipes that have been in service for five years or more and which have become rough on the inside is made by extending and modifying the Darcy Formula by the use of multipliers given in a table. These multipliers increase with the number of years of pipe service and are derived from a number of experiments made with such old pipe.

The book will be found a very convenient and compact hand-book for the use of those who have this sort of problems to handle, but, of course, as in handling the Kutter and other hydraulic formula the use of tables is a help, but does not do away with the necessity for an experience and skillfulness in judgment upon the part of the engineer. F. R. H.

Elementary Geology. By RALPH S. TARR. New York, The Macmillan Co. 1897. $1.40. Pp. xxx, 499. Figs. 268; plates 25.

Within a few months two books on geology for beginners have appeared; one by Professor Angelo Heilprin and the other the one before us. It is understood that a new edition of Professor Dana's elementary book is also in preparation by Professor Wm. North Rice, so that a third may be soon expected. Professor Scott's recent work, to be reviewed in our next number, is more advanced and, although a recent issue, it belongs in a different class and is adapted to older students.

The first thing that impresses the reader of Professor Tarr's book is the change in the amount of space allotted to the different branches of the subject, as contrasted with our earlier books. Of old it was the custom to enlarge on the historical portion of the subject, on the record of past events in the rocks, and on the remains of organisms now extinct that are found in the strata of the different periods. The interest of the student was usually excited by the significance of these, while the physical or dynamical phases of the subject were treated very largely as a key wherewith to interpret the conditions that surrounded the ancient organisms. The revival of the study of physical geography and its adaptation to youthful minds has led to shifting the preponderance of treatment to the physical side in Professor Tarr's book, and the historical portion embraces but a scant quarter of its pages. The author strongly advocates this method of presenting geology to youthful students and has many considerations of weight wherewith to fortify the contention. The operations of present-day forces and their results are always before us and they,

therefore, appeal more strongly to a school boy or girl than do the same things in past geological time, and, certainly, when a course in geology is meant to be introductory to one in physical geography, this method of treatment is inevitable. For older students it would be a grave error, and it is a little difficult for a reviewer, accustomed to teaching older students, to adjust his point of view sufficiently to appreciate the benefits of Professor Tarr's plan and to remember that the different character of his book's constituency may demand the change in presentation.

As is indicated by the number of figures, 268 and plates 25, the book is richly illustrated, and, in general, acceptably. For minerals or fossils, however, line sketches or drawings are much more significant than photographs, because the objects present so slight relief, and because the drawing, especially of a fossil, brings out the salient features better. The book is written in a facile and entertaining style, indicating that the author writes easily—a valuable gift, but one to be used with discretion in scientific work. J. F. K.

Metals, Their Properties and Treatment. By A. K. HUNTINGTON and W. G. MCMILLAN. Longmans, Green & Co. 1897.

The authors state in the preface that their object is to make clear the principles which have guided the evolution of the metallurgical arts and industries, avoiding multiplicity of detail which tends to obscure main issues, but in the preparation of this work it can hardly be said that they have attained success.

As regards the use of the work as a standard, the field covered is almost entirely English practice. American and German practice is scantily and shabbily treated as will be set forth in detailed criticism later.

Important practical details as to output, application, etc., are mainly conspicuous by their absence.

For instance, under Ore Crushing, no mention is made of the Gates crusher and under Stamps, while they are described in a general way with sufficient clearness to present a fair idea of construction, not a word is given as to screen sizes or outputs.

Likewise under roasting furnaces, from the description of construction an adequate idea can be formed of the various types, but as to whether 100 pounds or 100 tons can be treated daily, the students is left to search elsewhere. Under the blast furnace practice for pig iron an illustration is given entitled a "modern blast furnace," in which the only water cooled part is the tuyere and the blast pressure is quoted as 4½ to 5 pounds, giving a daily extreme output of 400 tons of pig iron.

To cite this furnace as a "modern" furnace or to quote these figures as modern practice is certainly misleading when we view the magnificent record of the Duquesne furnace of the Carnegie plant, water cooled from bosh downward, running under a blast pressure of 14 to 16 pounds and yielding the average monthly output of over 500 tons of pig iron daily, with a special run of 640 tons in one day.

Under the manufacture of open-hearth steel no illustration of the furnace is given, while our old friends of ancient utility, long since abandoned, the Blair furnace and the Siemen's rotary furnace, are graced with detailed illustrations. Under Bessemerizing copper mattes, no illustrations are given of the converters used and mention by name only is made of the trough converter, which is used to so great an extent in this branch of metallurgy.

The authors state that "it is not expedient, usually, to bring the molten matte from the furnace to the converter," while as a matter of fact modern practice is so to do. The converters at Great Falls, Butte, Anaconda, Arizona and elsewhere handle the molten matte direct from the furnaces to converters, either by ladle or bodily picking up the converter in a horizontal position by overhead crane and tapping matte direct, returning the converter to its stand for subsequent Bessemerizing. It is obvious that taking the molten matte direct from the furnace is economy in fuel. In ordinary smelting of ore to 50 per cent. matte, about 13 per cent. of fuel is consumed and to simply melt 50 per cent. matte in a cupola furnace requires 9 per cent. of fuel, so that in the present state of keen competition this important factor of economy is stated by the authors as being "usually inexpedient."

Under the electrolytic refining of copper this important branch of the subject is *fully detailed* in two pages of most general description. No idea is given of the size of anodes and cathodes, the number per tank, or the number of tanks generally employed and no mention is made of the two radically different systems, the multiple and the series. The details given are so misleading as to be valueless.

Another ancient friend, the Pattinsonage method of desilverizing base bullion, occupies seven pages fully illustrated, while the Parkes process of zinc desilverization, by which practically all desilverizing of base bullion is accomplished at the present time, is briefly dismissed in two pages.

These pertinent criticisms are condemnatory for the use of the work either as a general text-book or for correct information and its value from a practical standpoint is seriously called into question. It might be useful in teaching students from twelve to fourteen years of age or to obtain a cursory knowledge of the subject from a popular view.

It is to be regretted that the authors did not entirely rewrite the subject matter rather than amend the old work of Bloxam, published in 1872, as much of the original could have been omitted with profit, in view of the present conditions of practice.

The work consists of 562 pages, of good typography and good quality of paper, bound in board covers. J. S.

Elements of Mineralogy, Crystallography and Blowpipe Analysis. By ALFRED J. MOSES, Adjunct Professor in Mineralogy, Columbia School of Mines, and CHARLES LATHROP PARSONS, Professor of General and Analytical Chemistry, New Hampshire College. New York, D. Van Nostrand Co. Second Thousand. 1897. Pp. vii. and 342. Figs. 336. $2.

The first edition of this work was reviewed in the QUARTERLY of January, 1895, p. 190. The second edition differs only in the correction of certain observed errors. The work has met with a favorable reception and is used as a text-book in fifteen or twenty colleges and schools.

Problems and Questions in Physics. By CHARLES P. MATTHEWS, M.E., and JOHN SHEARER, B.S. The Macmillan Company, New York. 1897. $1.60.

This work is comprised of 243 pages, bound in board covers and of excellent typography and quality of paper. It is well illustrated by 107 carefully prepared cuts.

The subject treated is divided as follows:

Measurement and Units; Physical Tables; Directed Quantities; Graphic Methods; Averages; Approximations; Mechanics of Solids; of Liquids and Gases; Heat; Electricity and Magnetism; Sound and Light; Mathematical Tables; Answers; Index.

Each problem is numbered in consecutive order, and answers, when necessary, are grouped in a separate section at the last of the book.

The authors are to be congratulated in preparing so valuable a work for student use. It is admirably arranged and commends itself to all by its clear and concise expressions. J. S.

ALUMNI AND UNIVERSITY NEWS.

DEPARTMENT OF METALLURGY.

Professor H. M. Howe, of Boston, has accepted the professorship in metallurgy, dating from July 1st, the official time of Dr. Egleston's resignation. The university is to be congratulated in securing so able a man to fill the chair. Mr. Howe's high reputation as an expert in steel and the world-wide acceptance of his "Metallurgy of Steel," as the authority on the subject, endorse his abilities.

Since January 1, 1897, the date of Professor Egleston's withdrawal from active duties, the lectures in metallurgy have been in charge of Dr. Struthers. Professor Howe has kindly arranged to deliver a series of eight special lectures on steel, embracing its properties and its manufacture by the crucible, cementation and Bessemer processes.

Mr. W. B. Devereux, SCHOOL OF MINES, '78, has delivered six supplementary lectures on the general metallurgical practice in the West, dealing with the subject from an economic standpoint. Mr. Devereux's extensive practical experience renders him particularly fitted to deal with this subject in an able manner. The subject matter of these lectures will be published in the SCHOOL OF MINES QUARTERLY, beginning with the forthcoming issue.

On March 13th, the fourth-year students taking the lectures in metallurgy visited, under the supervision of Dr. Struthers, the works of the Nichols Chemical Company at Laurel Hill, N. Y. The departments dealing with ore roasting, copper matte smelting, Bessemerizing copper matte to blister copper, and the refining and casting of blister and cathode copper were carefully studied. The time was spent in a very profitable and interestingly manner. On behalf of the students and the department we wish to hereby publicly acknowledge the thanks due to Messrs. Heresshof, Ferguson and Masters for courtesy and attention shown. Their cordial reception added much to the pleasure of the trip.

On April 10th the same students, under charge of Dr. Struthers, visited the works of the Guggenheim Smelting and Refining Company, at Maurer's, near Perth Amboy, N. J., and were cordially received by Messrs. Allen and Eakins, the former in charge of the lead smelting and

refining department and the latter in charge of the electrolytic refining of copper.

The entire equipment was inspected and the course of the base bullion and blister copper to final products of lead, copper, gold and silver, was studied in detail.

The lead plant consists of four 65-ton softening furnaces and desilverizing kettles; furnaces for refining the lead from the kettles, each with its corresponding smaller kettle from which the refined lead is cast into bars; tilting retort furnace for distilling the zinc from the skimmings; cupelling furnaces for bringing the retort metal to fine bullion; furnaces for working up the antimonial skimmings to hard lead and two blast furnaces for treating all residues. Many interesting details of modern practice were studied, including the mechanical appliances for incorporating the zinc in the kettles and the "drying" of the zinc skimmings. The special construction of cupelling furnaces and others merited particular attention.

The refining of copper, as carried out here, consists of several large reverberations in which the crude converter metal or blister copper is refined and cast into anode plates. The electrolytic refining of copper is accomplished in a series of 400 tanks arranged in four divisions on the multiple system, with gravity circulation. The Cathode plates are shipped as such or refined. The residual mud in the tanks consists of the gold and silver of the converter metal with about an equal amount of copper; this mud has the copper removed by solution and the silver and gold melted down to Doré bars for the electrolytic separation by the Moebieus process. The day was most interestingly spent with profit to all and the thanks of the students and the department are heartily extended to Messrs. Allen and Eakins, whose courtesies were fully appreciated.

From the students standpoint the trips to smelters and refineries are of inestimable value, as thereby they are able to obtain the practical view of the subject-matter of the lectures. In addition their knowledge becomes more rounded as they acquire the practical as well as the theoretical considerations involved.

DEPARTMENT OF GEOLOGY.

Preparations have been in progress for removal next summer, and many preliminaries have been arranged. Materials not needed at present have been packed in boxes and have been gradually transferred to the new site, where, in the old asylum building, a storage room has been courteously assigned to the department by Mr. Darling.

Prof. Kemp had charge of the exhibits in Geology at the reception of the New York Academy of Sciences, April 5 and 6, and Mr. van Ingen of those in Paleontology. The exhibition was a most successful one, and in all departments Columbia was well represented.

A very interesting series of granite-porphyries and phonolites has recently been received from C. S. Herzig, Mines, '95, who collected them in the Little Rocky Mountains, while making some mining developments in this new region. The Little Rockies lie about 180 miles east of the main Rockies and rise as an insolated group in the plains of northeastern Montana. There has been some interest in the gold resources of the group, and

the mountains have been described geologically by Mr. W. H. Weed, Mines, '83, of the U. S. Geological Survey, and Professor L. V. Pirsson, of Yale. Mr. Weed has been doing a great deal of important and extremely interesting work in the small outlying ranges in Montana.

Monograph XXVII. of the U. S. Geological Survey has just been issued, and is entitled "Flora of the Amboy Clays." It is a posthumous work of Dr. Newberry's, and has been carefully edited and prepared for publication by Mr. Hollick, as the manuscript was left uncompleted by Dr. Newberry. The contributions of the Geological Department, embracing two separate and complete works, have now completed six volumes, and represent the work of the staff during the last six years.

Dr. A. A. Julien has been assigned to the Geological Department for next year, and will have special charge of the collections in Economic Geology and of rocks, and will offer some special courses. Dr. Julien will thus resume lines of work which occupied his attention in earlier years, and which have been unavoidably laid aside, meantime, for other duties.

DEPARTMENT OF MECHANICAL ENGINEERING.

The routine work of the Department is progressing at this time with the usual energy of the day when graduating theses are the principal thought of the Fourth Class. By the courtesy of the De La Vergne Refrigerating Company one of their seven-horse-power oil engines has been loaned and is the subject of one of the theses, while others are working upon the regular laboratory equipment. Comparative tests of injectors, tests of the efficiency of the Delaval ten-horse-power steam turbine and of the Otto gas engine, and of the efficiency of roller bearings for shafting and the like, are in progress at the same time that the regular routine work of testing is going on in almost the same space. The congestion of the mechanical laboratories makes the prospect of the relief at the new site a most agreeable one.

The laboratory has recently been enriched by the purchase of an interesting historical relic. The first patents in this country for successful shaft governing of high speed engines were taken out in 1873 by the late John C. Hoadley. To illustrate the working of these single-valve automatic engines with shaft governors, a model was exhibited at the Centennial Exhibition of 1876, and on the close of the exhibition was bought by the Merrimack Manufacturing Company of Lowell, where it has been used as a subsidiary and extra engine ever since. As the first engine built with a shaft governor, which is now almost universal in high-speed practice, the engine was of special interest and its possession as one of the experimental engines of the new laboratory of the Mechanical Engineering Department will be of notable significance.

The development of the Henry R. Worthington Laboratory has also been a subject which has been much before the Department during this winter. The steam-pump equipment, which forms the basis of Mr. Worthington's gift, embodies a triple-expansion duplex steam engine, having a capacity of 1,000 gallons a minute. This will discharge into a closed steel tank, within which the necessary pressure will be maintained from an air compressor operating at the same time that the pump is at work. The air will be delivered from this air chamber into over-head

tanks, from which the weir discharges will be taken and caught and measured in the necessary catch-tanks. For intermediate pressure, running up to 1,000 lbs. to the square inch, a second duplex pump operates with a steam accumulator, which forms a part of the machine itself and permits a wide range of special orifice work which the lower pressures of the first pump do not permit.

For investigations in a very interesting and, as yet, untried field, a third pump with its steam accumulator will carry pressures up to 5,000 lbs. to the square inch. It is believed that in these two latter fields, as well as in many of its other features, the Columbia Hydraulic Laboratory will be unequaled. In addition to these two other features, the Worthington gift includes meters of quite a wide range of capacity of the piston type, together with subsidiary and smaller hydraulic appliances, special gauges and the like.

By the kindness of friends of the head of the Department, the interest of other firms has been enlisted in coöperation in the equipping of the Department of the Hydraulic Laboratory. The Lawrence Machine Company, of Lawrence, Mass., by the active coöperation of Mr. Wm. O. Webber, of Boston, have consented to make a gift to the Laboratory of a centrifugal pump of their well-known pattern, having a suction orifice of 6 inches and a delivery of 5 inches. This gives a capacity of 600 gallons per minute under low heads, which will be mainly used, and there is an opportunity for the proper test of special hydraulic motors operating with volume rather than pressure. Stimulated by this example, the Morris Machine Works, of Baldwinsville, N. Y., have promised a similar gift, which is likely to take the form of a centrifugal pump, with its special direct couple engine, making a superb piece of laboratory apparatus, because the engine becomes an experimental steam engine with its resistance directly coupled to it and directly measured. The Rife Hydraulic Engine Manufacturing Company, of Roanoke, Va., contribute one of their No. 40 engines, operating a double-action hydraulic ram engine with 4″ drive pipe and lifting from 35 to 75 gallons per minute. The Builders' Iron Foundry, of Providence, through their Treasurer, Mr. R. A. Robertson, contribute an 8″ Venturi Meter, which it is expected to use in connection with the tests to be made upon the centrifugal pumps and in general hydraulic operations upon a large scale. Negotiations are in progress for adding the types of water-moving machinery which are still lacking, to make the Laboratory absolutely complete, as a sample of its class, but enough has already been promised as the result of the winter's effort to make the authorities feel that they are justified in the claim that the Mechanical Engineering Department in this field will be far in advance of anything to be found elsewhere in this country, and if this is true then in the world.

In the other lines of development the coöperation of interested donors has also been most helpful. The machinery of transmission is to be very materially strengthened by gifts from the Dodge Manufacturing Company, of Mishawaka, Ind.; from the Automatic Friction Clutch Company, of Erie, Pa.; from the Rockwood Manufacturing Company, of Indianapolis, Ind.; from the Almond Clutch and Coupling Company, of which the exact detail will be made public at a later date.

In the Department of Steam Engineering for the equipment of the Laboratory the advantages have been much considered and have been

decided upon, so far as possible, of giving to the power machinery of the laboratory the complexion of air compressors. The air compressor, as a type of experimental steam engine, offers some notable advantages. It contains its own resistance, which can be large and up to the full capacity of the steam cylinder. The resistance is clean and easily controlled. The resistance is measured by the same appliances which are used in measuring the effort of the steam, and the resistance can be stored and used again in motors of the same class as the original compressing and steam cylinder whereby the complete circuit of performance can be studied. If, in addition, the air compressor can be made of a type involving several stages, both in the steam and its air end, an additional and most interesting group of combinations is made possible by the use of reheaters between the steam cylinders and intercoolers between the air cylinders. Farthermore, this kind of experimental steam engine opens up the field in which variations of temperature, as well as variations of pressure, can be introduced and the general subject of mechanical refrigeration. There is still, at this writing, a wide opportunity for developments of the Testing Laboratory, which has, as yet, received no attention.

The subject of the mechanics of hoisting, as applied in hydraulic elevators, is to be made a special feature of opportunity for study by the provisions in the Otis elevator, which is to be put up in the Engineering building for the attachment of all sorts of measuring and dynamometric appliances. This elevator is a gift to the University by the Otis Company, who have, in addition, given to the machine this special educational bias. Similarly the ventilation of the big laboraory of Mechanical Engineering is done by a specially-fitted Sturtevant blower, which, with its appliances, becomes the nucleus of a pneumatic laboratory. The University is indebted for this to the combined interest of Messrs. G. A. Suter, Alfred A. Wolff and the Sturtevant Company, of Boston.

Professor Hutton's book, which he has called the *Mechanical Engineering of Power Plants*, appeared in February, and is in use as a text-book in his department in the second and third-year electrical courses, and in the third and fourth-year of the other engineering courses. It embodies and extends the courses in engines and boilers which so many graduates will remember (Alumni may perhaps read the dedicatory paragraph at the close of the preface with interest), and the method of using the text-book seems to be working well. The projecting lantern with electric arc lamp is used in the light room without darkening by shades to throw upon the screen views of either the type illustrated, or better still of variants from the type in the text, and the recitations are based upon these projections, so as to make the class-room exercise resemble what in other departments is called a clinical exercise. So far from the use of a text-book taking from the value of the class-room instruction, and making the personal factor of the instructor less important, this method tends to give greater value to the oral instruction than under the former lecture system, while admitting of enormously greater thoroughness and exhaustive treatment.

SUMMER SCHOOL IN PRACTICAL METALLURGY.

The class in Practical Metallurgy will convene at Chicago, Ills., immediately after the completion of the time devoted to the Summer School in Mining (July 8th or 9th).

The metallurgical works at and near Chicago and Pittsburgh will be visited and studied in detail. Probably most of the time will be spent at Chicago. It is expected that Prof. Henry M. Howe will be present to take charge of the class, assisted by Dr. Struthers.

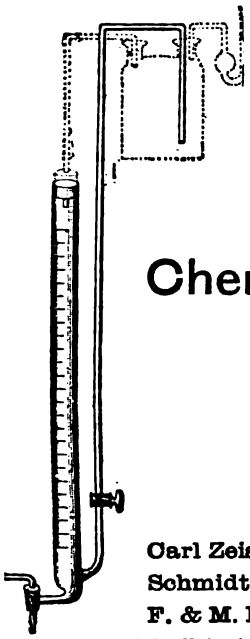
It is the intention this year to devote the greater part of the time to the subject of iron and steel, as the facilities offered are unsurpassable; Chicago and Pittsburgh being the two great steel centers of the United States.

This practical summer school in metallurgy is a new feature in the course of instruction, and was inaugurated last year by Dr. Struthers, who took charge of the students at Butte, Mont. The class devoted their time to the study of the smelting of copper and silver ores as carried on in that district.

The class was then optional and it is very gratifying to note the full attendance of the students and the excellent quality of their work (a full description of the Summer School at Butte can be found in the SCHOOL OF MINES QUARTERLY, Vol. XVIII., No. 1, p. 66.) By varying the subject each year, better results, as regards general education, can be obtained.

UNIVERSITY BULLETIN.

The *University Bulletin* is issued by the Columbia University Press, with the approval of the Trustees of the University. It is addressed to the Alumni, officers and friends of the University, and its purpose is to publish articles of interest on topics that concern the University as a whole, to furnish pertinent information with regard to the University and its separate schools, and to give a summary of important University legislation. The *Bulletin* will appear three times during the academic year, and, until further notice, will be sent free of charge to such Alumni of the University as may signify their desire to receive it. Numbers I–XIV will be sent postpaid by the Macmillan Company, 66 Fifth Avenue, New York City, on receipt of two dollars; single numbers will be supplied at twenty cents each. Since its foundation, in 1890, the *Bulletin* has contained a large amount of interesting and valuable matter relating to the University in its period of growth and reconstruction, and a complete set of its numbers is virtually indispensable to Alumni who preserve important publications bearing on the history of the College and the University.



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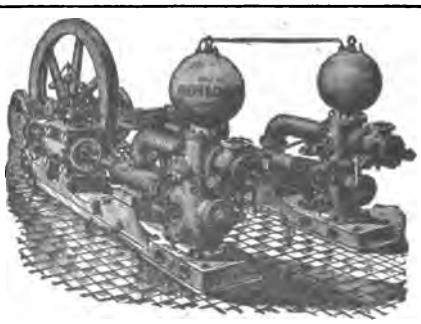

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VOL. XVIII. No. 4. JULY, 1897.

THE SCHOOL OF MINES QUARTERLY.

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CONTENTS:

Notes on Air Compressors. II. By Robert Peele..... 309
Notes on the Present Western Practice of Metallurgy—Economically Considered. By W. B. Devereux..... 348
Principles of Electrical Distribution. III. By Francis B. Crocker..... 366
An Introduction to the Study and Experimental Determination of the Characters of Crystals. By Alfred J. Moses, Ph.D..... 385
Professional Draughtsmen as Special Students in the School of Architecture. By Professor William R. Ware..... 422
Abstracts in Analytical Chemistry. By Elwyn Waller, Ph.D..... 430
Book Reviews..... 445

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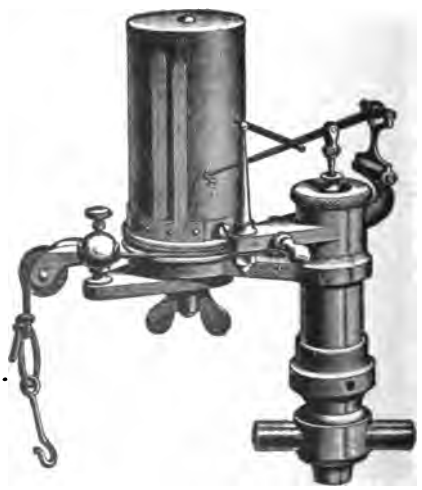

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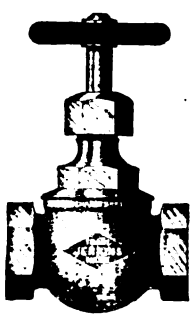

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THE

SCHOOL OF MINES QUARTERLY.

VOL. XVIII. JULY, 1897. No. 4.

NOTES ON AIR COMPRESSORS.*

BY ROBERT PEELE.

PART SECOND.

TABLE OF CONTENTS.

	PAGE.
INLET VALVES	310
Spring poppet valves	310
Johnson valve	313
Humboldt rubber ring valve	313
Rand mechanical gearing	314
Sturgeon annular valve	315
Riedler mechanically controlled valve	316
Norwalk adaptation of Corliss valve	318
Ingersoll-Sergeant piston inlet valve	319
ADMISSION OF AIR TO CYLINDER	320
Importance of low temperature of intake air	320
DISCHARGE OR DELIVERY VALVES	321
Spring and mechanically controlled discharge valves	322
AIR RECEIVERS	322
Dimensions and construction	322
Functions	323
Underground receivers	324
AIR PRESSURE REGULATORS OR UNLOADING DEVICES	324
Clayton air governor	325
Norwalk regulator	326
Ingersoll-Sergeant regulator	327

* Continued from p. 226 of April QUARTERLY.

CONVEYANCE OF COMPRESSED AIR IN PIPES 328
Character and amount of losses. 329
Formula for calculating friction 229
Table of capacities of piping of different diameters and lengths. 332
FREEZING OF MOISTURE DEPOSITED FROM COMPRESSED AIR 333
Effect of external cold during transmission. 334
Effect of cold produced by final expansion. 334
COMPRESSED AIR USED EXPANSIVELY 335
REHEATING COMPRESSED AIR. 336
Objects and results. 337
Practical limits of temperature in reheating. 338
DUTY OR CAPACITY OF AIR COMPRESSORS 338
Theoretical and actual capacity. 339
AIR COMPRESSION AT HIGH ALTITUDES 340
Reduction of Compressor Capacity 340
EFFICIENCY OF PRODUCTION AND TRANSMISSION 341
Losses in production. 341
Losses in transmission and use. 342
Total efficiencies. 342
AIR COMPRESSION BY DIRECT ACTION OF FALLING WATER 343
REFERENCES 347

INLET VALVES.

The proper design and working of the inlet or suction valves exert an important influence upon the efficiency of the compressor. In the older forms of wet compressor various patterns of clack-valve were employed, as exemplified in the Dubois-François compressor, but more recently poppet valves have come into very general use. These are furnished with springs and are actuated either by difference of air pressure alone, or are controlled by mechanical means. The Corliss valve also has been successfully adapted, and latterly a piston inlet valve has met with much favor.

The two chief requisites of inlet valves are:

1. That they shall have a sufficient area of opening to permit free entrance of air.

2. That they shall open readily at the beginning of the stroke with a minimum of resistance, remain open until the end of the stroke, and then close promptly.

Poppet Valves. One of the commonest forms is the mushroom valve (Fig. 17). While the total inlet area of the cylinder should be ample, there are two special requirements in the case of ordinary poppet valves: (1) the area of each individual valve must not be too great, or it will become too heavy; (2) the lift must be small, in order to attain a prompt opening and closure and to reduce "chattering." For these reasons several independent

valves, generally from four to six, are set in each cylinder head. Both valve and seat are of brass. In some compressors, *e. g.*, the Clayton, the seat is flat and covered by a slightly elastic packing ring. Usually, however, the contact is between metal and metal, with surfaces ground true, and the seating is often coned. The valve stem is provided with a spiral spring to keep the valve on its seat, and works in guides cast in one piece with the seat and valve casing. The valve is screwed into the cylinder head so as to be readily removed when necessary. Brass springs are always used to avoid the effects of corrosion, and must be easily compressible to allow the valve to open freely under a very small difference of pressure. These springs should be made of the best material and accurately proportioned to present the requisite resistance. The ordinary poppet valve is opened by the atmospheric pressure without, when a certain degreee of rarefaction inside the cylinder has been caused by the movement of the piston; that is, when the difference of pressure becomes sufficient to overcome the strength of the spring and compress it. To accomplish this the piston must advance some distance before any air can enter the cylinder. Therefore, with the common poppet valve, a full cylinder of air cannot be taken at each stroke, and some loss of capacity ensues. More or less irregularity in the entrance of the air must take place also, because, while the pressure of the outside air tries to open the valve, the action of the spring tends to keep it closed. This produces "chattering" or "dancing" of the valves, and has led to the introduction of various mechanical devices for controlling them, as will be noted later.

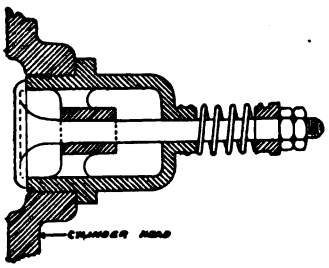


FIG. 17.

As the springs soon lose their elasticity, and undergo alterations in their strength, they require careful watching and regulation; outside adjusting nuts on the valve stems are provided for this purpose. If the springs be too slack the chattering increases, and if too tight they present excessive resistance to the entrance of the air. This resistance, the effect of which is shown on the diagram (Fig. 18), should be reduced so far as practicable, but of necessity must always amount to something. The point *b*, where

the compression line crosses the atmospheric line *d e*, is the point of the stroke at which the inlet valves open, and the volume passed through by the piston in traveling from *a* to *b* measures the loss in the capacity of the compressor from this cause. Furthermore, there is usually sufficient throttling of air in passing through the inlet valves to keep the admission line *a c* at an appreciable dis-

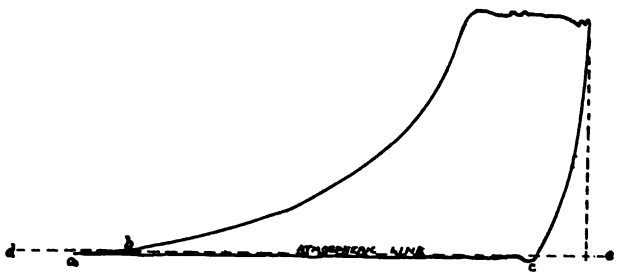
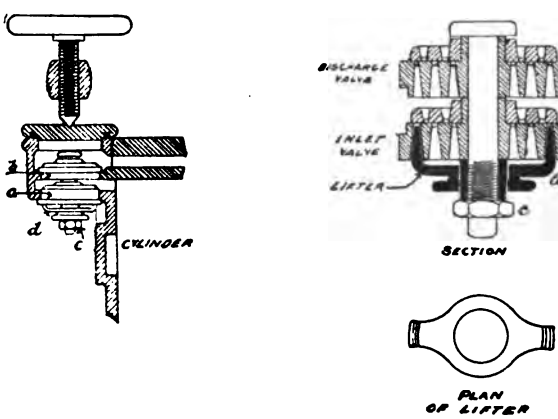


FIG. 18.

tance below the atmospheric line until near the end of the stroke. The area below the atmospheric line, therefore, represents the resistance due to negative or suction pressure. If the inlet valves be too small, or badly designed, the loss may amount to as much as two or three lbs. per sq. in.*

Notwithstanding these inherent disadvantages, the poppet valve is widely used because of its simplicity. In case of leakage due to cutting and wear of the seating surfaces the valve is easily re-



FIGS. 19 AND 20.

* Goodman, Trans. Fed. Inst. Min. Eng., Vol. VII., p. 240.

moved and re-ground. These valves are employed in a number of well-known compressors, such as the Rand and Clayton. Following are descriptions of several variations from the ordinary mushroom type of poppet valve.

Johnson Valve. In the Johnson compressor, built in England, there is a single poppet inlet valve of the grid-iron type at each end of the cylinder. It has a large area, with a small lift, and is mounted in a peculiar way on the same spindle with the discharge valve (Figs. 19 and 20). Both valves are rendered easily accessible by being placed in a chamber projecting horizontally from the top of the cylinder. This chamber is closed by a cast-iron plate held in place by a yoke and set-screw. The lift of the valve is controlled by an outside adjusting nut, *c*, on the spindle. The inlet valve is provided with a "lifter" (Fig. 20, *d*) by which it can be raised from its seat and thrown out of use, if it be desired temporarily to make the compressor single-acting. Springs are not used with the Johnson valve; it closes by gravity only.*

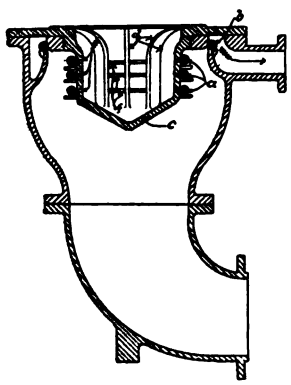


FIG. 21.

Humboldt Rubber Ring Valve. The older form of Humboldt wet compressor (German) has a simple and ingenious valve (Fig. 21). It consists merely of a rubber ring of round cross-section which covers a series of slits in a cylindrical casting set in the top of each air chamber. Three of these rings, *a*, with the slits, *f*, comprise the inlet valves in each end of the air cylinder, the casting, *c*, in which they are placed forming a part of the valve chamber cover. The casting, *c*, is strengthened by a series of webs, *d*. As the pressure in the air chamber falls the atmospheric pressure expands the rubber rings, forcing them away from the slits, and allowing air to enter. Then on the reversal of the stroke the elasticity of the rings causes them to tighten up on their seats and close the seats. The valve openings are relatively large and permit free entrance of air. The discharge valve, *b*, has the same construction, but consists of a single ring only, of larger cross-section. These rubber valves are found to last well, as they are kept wet and are not exposed to any great degree of heat.

* Ph. R. Björling, *Coll. Guardian*, August 7, 1896, p. 272.

MECHANICALLY CONTROLLED VALVES AND VALVE MOTIONS.

The difficulties inseparable from the use of inlet valves which for their opening and closure depend upon difference of air pressure have led to the introduction of various mechanically controlled valves. By their use fewer valves are required, as a rule, because they may be made much larger and have a higher lift. As distinguished from ordinary poppet valves they are operated or controlled by being in some way connected with the moving parts of the compressor. In this way the compressor is enabled to take more nearly a full cylinder of air at each stroke.

Rand Mechanical Valve Gear (Fig. 22). A system of levers is

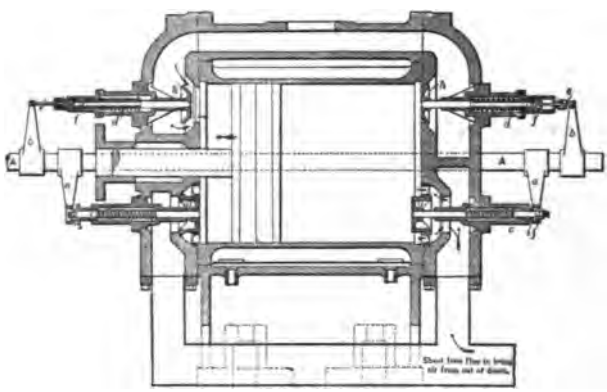


FIG. 22.

employed to release the valves at the proper time from the pressure of their springs, thus permitting them to open freely. The spring still serves to assist in closing the valve, and is stronger than in the common poppet valve. The releasing arms, *a*, *b*, are mounted upon a horizontal bar, *A*, which has a slight reciprocating movement derived through connecting links from the valve motion of the steam cylinder. These releasing arms are connected with the stems of both inlet and discharge valves by sliding joints, *j*, *j'*. Another design has a pair of outside horizontal bars, one on each side of the cylinder, connected by cross-heads, and carried in bearings attached to the cylinder casing. These cross-heads take the place of the arms, *a*, *b*. The connection between the mechanical gear and the valves is in a measure positive; the inlet valves open promptly at the beginning of the stroke and remain open

without chattering until, at the end of the stroke, the pressure of the arms is removed and the springs are allowed to act. To accomplish this the gearing releases the pressure of the spring a little in advance of the beginning of the stroke, so that the valve is at liberty to open fully at once. As the valves are much larger than ordinary poppets, usually but one inlet and one outlet valve are set in each cylinder head. In a large two-stage compressor at the Dominion Coal Co.'s mine, Canada, there are two mechanically controlled inlet valves on each end of the low-pressure or intake cylinder.

Halsey's Positive-Motion Air Valve Gear. This gear was brought out in 1891, and is now being made by the Canadian Rand Drill Co. The control is effected by a system of horizontal levers, linked together and driven by a cam movement from a prolongation of the steam cut-off valve stem. There is one inlet and one discharge valve at each end of the cylinder. The movement of the inlet valve lever is so timed as to close the valve when the crank passes its center, and then to move away from contact with the valve in time to permit it to be opened by the air pressure. As no springs are used the valve has a high and free lift. All the parts are easily accessible. This gear is similar in principle to the Riedler mechanical gear described below, but was invented independently in this country.

Inlet Valve at the Lens Colliery, France. Here a cam movement has been successfully employed (Fig. 23). The stem of the inlet valve is provided with a spiral spring and projects from the cylinder head, as usual. At the beginning of the stroke the valve is opened rapidly by a cam, *a*, of peculiar shape, playing against the end of the stem. The cam is mounted upon a small shaft which is geared to revolve once for each revolution of the engine. At the end of the stroke the cam allows the valve to close under the action of the spring.*

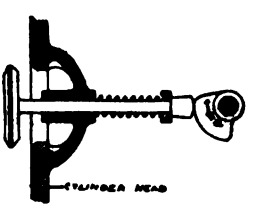


FIG. 23.

Sturgeon's Inlet Valve. This ingenious valve, of an air compressor made in England, furnishes another example of a positive movement. It is a large annular valve, *c* (Fig. 24), encircling the piston rod in each cylinder head, and is operated directly by the move-

*H. W. Hughes, Text-book of Coal Mining, p. 55.

ment of the piston rod itself.* The connection between the valve and rod is frictional only, being brought about by a gland, *e*, which serves to form a stuffing box for the piston. By tightening or loosening the nuts, *a*, of the bolts by which the gland is attached to the valve flange any desired amount of grip upon the piston rod can be obtained. Thus the valve moves with the rod and opens as soon as the piston begins its stroke. Flanges on the ends of the valve limit its play in each direction, controlling the amount of lift and area of opening. The valve and stuffing box together form the bearing of the piston rod in each cylinder head. At the end of the stroke a recess in the piston receives the large inner flange of the valve so as to diminish the clearance. The mechanism is simple and its work satisfactory.

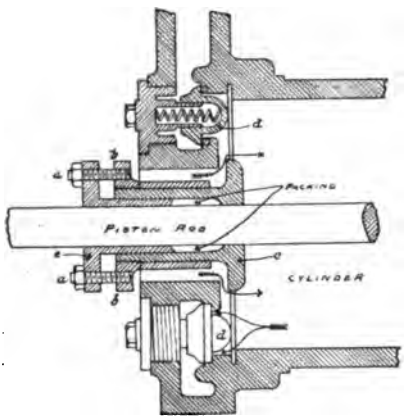


FIG. 24.

An arrangement resembling the above is used in a very good compressor made by the Dover Iron Co., Dover, N. J.

Riedler Valve. The mechanically controlled Riedler compressor valve is similar in principle to that used in the Riedler pump. There is usually one inlet and one discharge valve at each end of the cylinder, controlled by mechanism receiving its motion from an excentric on the fly-wheel shaft (Fig. 25). The excentric imparts motion to a wrist-plate connected by links to transverse rocker shafts passing into the valve chambers. At each end of the cylinder is a pair of these valve chambers, or chests, one containing the inlet, the other the discharge valve. The inlet valve is controlled by a forked arm, mounted upon the rocker shaft inside the valve chamber and extending out over the valve. The valve spindle, provided with a spiral spring, passes between the arms of the fork, which is raised and depressed according as the valve is to be closed or opened. A similar arm upon the same rocker shaft operates the discharge valve, though of course in a reverse sense. The valve as originally designed by Riedler has undergone modifica-

*Ibid, p. 53.

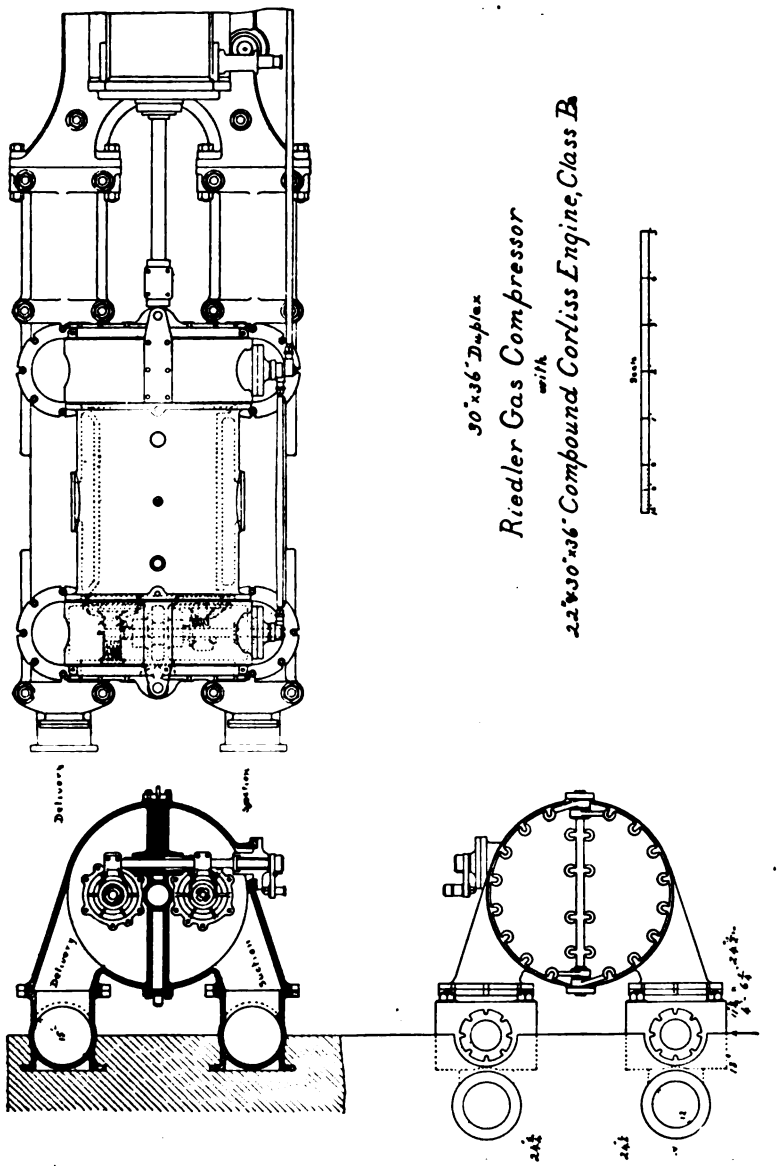


FIG. 25.

tion in some of its details. One form has two entirely distinct parts: the body of the valve, or "catcher," and a light ring which forms the seating part. This ring is a thin steel disc lying loosely be-

tween the catcher and the valve-seat. The catcher, which is operated positively by the fork, merely guides and limits the movement of the loose valve ring. When the catcher is withdrawn by the pressure of the fork against the spiral spring, just before the end of the piston stroke, the loose ring still remains seated; then on the reversal of the stroke the ring is instantaneously lifted by atmospheric pressure, places itself against the catcher, and remains there until the end of the stroke. It is then forced upon its seat promptly by the fork and catcher. To guard against breakage due to any inaccuracy in the movements of the closing fork, which might result from wear of the parts, another spring is provided. This is mounted upon the valve stem, between the fork and the top of the catcher, and allows for slight variations of movement. The use of the light independent valve ring, which is moved by a very slight difference of pressure, constitutes one of the important features of the Riedler valve.

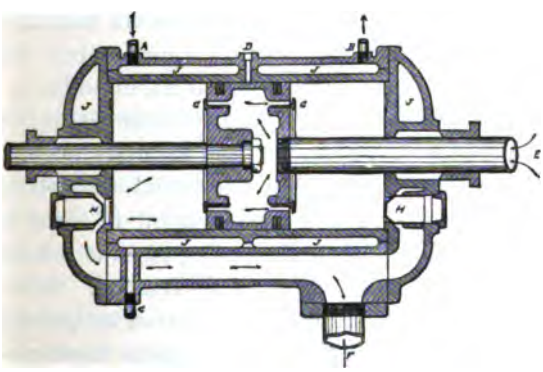
Latterly several alterations have been introduced to render smoother the working of the valves, and to make them easier of access for adjustment. In a recent design by Fraser and Chalmers the closed valve chambers of the ends of the cylinder are done away with, and the rocker shafts, with their forks, are outside, so as to be readily reached.

Norwalk Valve. Since 1881 the builders of the Norwalk compressor have used successfully an adaptation of the Corliss valve gear. One inlet and one discharge valve are set in chests at each end of the low pressure or intake cylinder. The main valve rod, *a* (Fig. 26), is driven by a drag or return crank, *b*, attached to the

FIG. 26.

main crank pin. The rod connects with a lever, *c*, operating the forward inlet valve, and from this lever a shorter rod, *d*, passes to a corresponding connection with the inlet valve at the other end of the cylinder. Still other links, *e*, pass from each inlet lever to the respective discharge valves. An important detail of this valve motion is the cams, *f*, *f*, which form a part of the valve levers. The cams of each pair of valves, inlet and discharge, work together, rotating the valves in opposite directions. They are so shaped as to roll upon each other as the connecting links, *e*, move the valves. This device does away with the necessity for springs and makes the whole movement accurate and positive. For the high-pressure air cylinder of the Norwalk compresser the valves are of the poppet pattern.

Ingersoll-Sergeant Piston Inlet Valve. In the Ingersoll-Sergeant compressor the inlet valves are placed in the piston (Fig. 27). The



AIR INLET VALVE.

A—Cold Water Inlet.
B—Cold " Discharge
C—Jacket Drain.
D—Oil Hole for Automatic Oil Cup.
E—Air Inlet.
F—Air Delivery.
G—Inlet Valves.
H—Delivery Valves.
J—Cold Water Jacket

FIG. 27.

piston is hollow, and into its rear end is screwed a hollow back piston rod passing out through a stuffing box in the back cylinder head. There are two large ring-shaped valves, *g*, *g*, made of composition metal, one on each side of the piston. (See also the perspective cut *v*.) These valves rest in their seats without springs or other connection, except that in the piston casting there are several small studs which extend through slots in the valve ring. While the compressor is running the air is drawn in through the hollow piston rod in an almost constant stream, passing through either valve first into one end of the cylinder and then into the other. At the beginning and end of each stroke the valves are

alternately opened and closed by their own inertia, as the piston reverses its motion. The valve in that face of the piston which is toward the direction of movement is always closed, while the other is open for the passage of the air entering through the hollow rod at *e* into the cylinder behind the piston. On account of the large size of the valves their throw, or lift, is only about one-quarter inch. It is probable that during admission there is a less difference between the pressure of the air taken into the cylinder and the atmospheric pressure than with any form of spring controlled valve, for, meeting with no resistance due to springs, the air enters freely. Moreover, "at the moment when the end of the stroke is reached the inflow of air is suddenly stopped, and the momentum of the column of air in the inlet pipe causes it to act as a rammer upon the body of air in advance of it, thus actually raising the air pressure within the cylinder above the pressure without."* In other words, the compression begins with a greater weight of air in the cylinder than when other methods of admission are employed. These valves wear well, and their use permits a moderately high piston speed. Three advantages of the piston inlet, in addition to those noted above, may be mentioned: 1. The cylinder castings are simplified. 2. The space in each cylinder head formerly occupied by poppet inlet valves is now devoted to additional water-jacket area, just where the air pressure and development of heat are greatest. 3. The number of moving and wearing parts is reduced.

Arrangements for Admitting Inlet Air to the Compressor. It is of great importance that the inlet air shall be as cool as possible. The colder the air the smaller the volume occupied by a given weight of air taken into the compressor and the greater the output. Taking in warm air involves loss of capacity and of economy in production. Mr. Frank Richards points this out in a convincing and simple way.† "The volume of air at common temperatures varies directly as the absolute temperature. With the air supply at 60° its absolute temperature is 521°, and its volume will increase or decrease $\frac{1}{521}$ for each degree of rise or fall of temperature. Therefore, if in securing the supply of air we can get a difference in our favor of 5° * * * we accomplish a saving of about 1 per cent. If a difference of temperature of 10° can be secured 2 per cent. is saved," practically without cost. The practice of tak-

* *Eng. and Min. Jour.*, March 23, 1895, p. 270.

† Compressed Air, p. 55.

ing air from the engine room is a common one at mines, and is bad, not only because such air is usually heated to a considerable degree, but also because it is apt to be charged with dust which causes unnecessary wear of valves and piston.

Some means should be provided to convey to the compressor fresh air, taken preferably from some point outside of the building. A box or pipe of wood is better than one of iron, because of the smaller conductivity of wood. Its cross-section should be sufficient, say at least one-half the area of the cylinder, to avoid loss from friction. To make such a connection conveniently the inlet valves should be enclosed in a sort of external air chest on each end of the cylinder, such as that of the Norwalk compressor. Some compressors are not well adapted for making this arrangement. Of course in winter a greater saving can be effected than in summer, but even in warm weather some advantage is gained, especially if the air conduit opens on the north side of the building, out of reach of the sun.

Discharge or Delivery Valves.

As the discharge valves are for the passage of the air after compression, a less total area is required than for the inlet valves, but they must not be too small or the friction will become excessive. It is important also that they should not leak, since the passage of even a small quantity of compressed air back from the receiver pipe into the cylinder would be equivalent to the loss caused by a large clearance space.

Discharge valves are usually of the poppet type, as has been noted in the foregoing description of the various valve movements. While they differ somewhat in detail the same general principle is followed by nearly all.

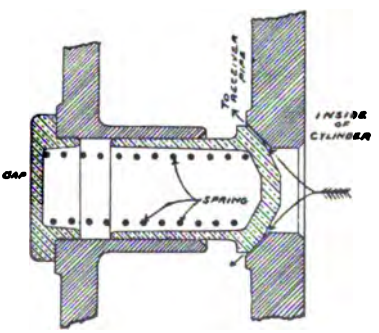


Fig. 28.

One of the commonest forms is the cup-shaped poppet, with an internal spring (Fig. 28). Sometimes the spring encircles the valve. To make it easier to keep them tight the seating surfaces are of brass, and coned like the inlet valves. Several discharge valves are usually employed, en-

closed in chambers with which is connected the pipe leading to the air receiver. To render the valves readily accessible they are covered by caps screwed into the cylinder head, and can be removed separately for repairs and regulation of the spring.

In the Norwalk compressor, as has been seen,* the Corliss pattern is used for discharge as well as for inlet valves, except in the high-pressure cylinder, where poppet valves are employed. With the Rand mechanical valve gearing the discharge valves do not differ in general form from the inlet valves. The same similarity in principle between inlet and discharge valves is to be noted in the rubber ring valves of the Humboldt compressor (Fig. 21) and in the mechanically controlled Riedler valves.

It should be observed that mechanical contrast of the discharge valves is unsatisfactory under certain circumstances. If the air pressure in the receiver be subject to considerable fluctuations, due to irregularity in using the air, the receiver pressure at times will be below the pressure in the cylinder at the end of the stroke. That is, the valves may be subjected from within to a heavy pressure, but are prevented from opening until the controlling mechanism is released. Then, when the valve is permitted to open the pressure drops suddenly to that in the receiver.† This difficulty is in part overcome by the use of air-pressure regulators, described hereafter. It is also avoided in the Riedler and the Halsey valve movements, in which the opening is governed by the air pressure and not by the mechanical gear.

Air Receivers.

An air receiver is used almost invariably in connection with compressors. It consists of a cylindrical plate, iron or steel shell, resembling a steam boiler in construction. Its size varies from say 30 in. diameter by 6 ft. long up to 48 in. diameter by 12 or 16 ft. long (Fig. 29). It should be placed not over 50 ft. from the compressor, and may be set either vertically or horizontally. Attention should be given to arranging the inlet and outlet pipes in proper relative position. If directly opposite and pointing towards each other a strong current is caused, which greatly reduces the usefulness of the receiver in cooling and draining the air. A good plan is to make the inlet connection on one side near the

*April number of the QUARTERLY, p. 201, Fig. 3.

† Goodman, Trans. Fed. Inst. M. E., Vol. VII., p. 239.

end, and the outlet at the center of the head at the other end. Or, as shown by the cut (Norwalk receiver), both pipes may enter near the top, but the outlet is carried through the receiver (see dotted lines) nearly to the bottom. The outlet pipe should take air from near the bottom, where it is likely to be slightly cooler.

The principal functions of the receiver are: (1) to compensate for the pulsating effect produced by the strokes of the compressor; (2) to cool the air as much as possible before it enters the main; (3) to prevent rapid fluctuations of pressure and excessive friction, due to irregularity in the use of the air; (4) with wet receivers, to drain off the water carried over with the compressed air. In the receiver the velocity of the air is greatly reduced, so that it has opportunity to cool somewhat and to deposit a part of the moisture in suspension which otherwise would be conveyed into the main. Even with dry compressors a little water collects in the receiver from the natural moisture of the atmosphere, especially during warm weather. At intervals this water is drained off at the bottom by a cock provided for the purpose. The receiver is furnished with a man-hole, pressure gauge and usually a safety valve with a weight for graduating the pressure as desired. Receivers are best made of steel plate to stand working pressures of 100 to 110 lbs. per sq. in. They are single-riveted on circular seams, double-riveted on longitudinal seams. The heads are usually dished, sometimes hemispherical. It is customary to test receivers with say 165 lbs. cold-water pressure for working up to 110 lbs.

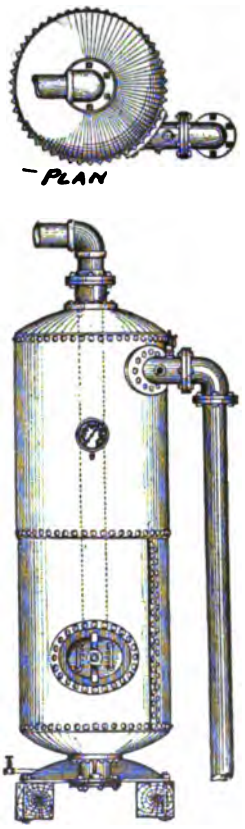


FIG. 29.

A receiver acts to a limited extent as a reservoir of power. But, to be of any real service in this way its capacity must be large. For example, take a 20-inch compressor, working at 60 lbs. pressure to supply air for a regular consumption. To enable the receiver to meet the demand for only one minute after the com-

pressor stopped, and not have the pressure fall more than 15 lbs., it would have to be 5 ft. diameter by 50 ft. long. Again, if the compressor were running at a constant speed and the demand for air should suddenly increase 25 %—as might happen in starting several more machine drills—a receiver of the size mentioned could meet the extra demand only four minutes.* It is thus evident that while a receiver is useful as an equalizer within certain limits, yet, unless it be very large, the pressure might quickly run up to an unreasonable amount in case of an unexpected decrease in consumption of air. Long pipes of large diameter assist in equalizing the flow of air, but their use does not preclude the necessity of receivers, and it is much cheaper to employ piping of moderate size.

Underground Receivers. When the air main is very long it is advisable to place a second receiver near the place where the air is being used. A more uniform pressure is in this way maintained, and as excessive fluctuation in the velocity of flow is avoided, the friction and consequent loss of pressure between the two receivers become practically constant. Underground receivers are not often used for air drills alone, but they became a necessity when large machines, such as pumps and hoists, are run by compressed air. They are useful, moreover, in permitting a further deposition of moisture from the air.

In construction underground receivers are usually similar to those at the compressor. At the Mansfeld copper mines, Germany, another method of construction has been adopted. Chambers are excavated in the rock, all loose stone removed, and the walls cemented tight. The chamber is closed by a brick dam composed of two parallel walls, with a 2-inch layer of cement between them. In the dam are set a 20-inch cast-iron man-hole pipe with suitable cover, several pipes for connecting with mains to the various working places, and a drain pipe and cock close to the floor. A pressure gauge is attached to the man-hole cover. This reservoir is said to have cost only one-third as much as an iron receiver.*

Air-Pressure Regulators.

In most cases compressors for mine use are employed in furnishing air for rock drills. When running at a moderate speed

* Norwalk Iron Works Catal., 1896, p. 51.

* Foster, Ore and Stone Mining, p. 169. Abstract Zeitschrift für das Berg-, Hütten- und Salinen-Wesen, Vol. XLI., 18 3, p. 119.

the compressor should be large enough to supply the necessary volume of air, at the proper pressure, for all the machines intended to be kept at work. But rock drills are always operated more or less intermittently, so that, unless a large number of them are supplied from the same plant, the rate of consumption of air will vary considerably, and at a constant compressor speed the receiver pressure will fluctuate. When the demand is small, or ceases altogether, the pressure rises rapidly and the compressor must be slowed down, or air will be blown off at the safety valve of the receiver. To prevent such loss of work, and to relieve the engineer of the close attendance required for regulating the speed of the compressor so as to avoid blowing off air, automatic pressure regulators, or unloading devices, are employed. They are arranged to control the admission of steam, shutting it off automatically when the pressure reaches the fixed limit, and admitting it again when increase of consumption causes the pressure to fall. The following regulating devices may be taken as examples.

Clayton Air Governor. In one form of this governor the main steam pipe is provided with a special throttle (Fig. 30a), resembling a safety valve in having a lever and weight, *b*, connected with the valve stem, *c*. Close alongside of the throttle valve, and for convenience clamped upon the main steam pipe, *d*, is a small air cylinder, *e*, the upper end of whose piston rod is pinned at *f* to the weighted lever. Entering the bottom of this air cylinder is a small pipe, *g*, from the air receiver. When the pressure in the receiver exceeds the assigned limit the weighted lever is raised and partially, or wholly, closes the steam throttle, *a*. Then, when the air pressure has been reduced by the slowing down of the compressor, and by consumption of air from the receiver, the weight falls and reopens the throttle.

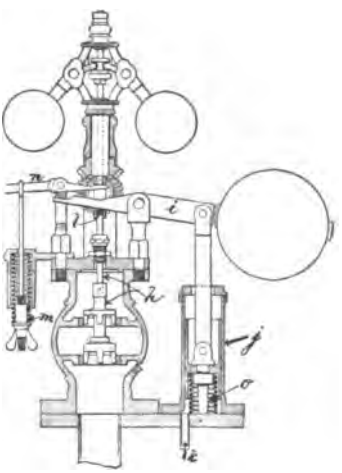


FIG. 31.

Another form of regulator, shown in section by Fig. 31, is also sometimes used on Clayton compresosrs. The stem of the throttle, *h*, is provided with a ball governor whose action is controlled by

the introduction of the weighted lever, *i*, and the small air cylinder, *j*, which are similar to those in Fig. 30. Air from the receiver enters the cylinder, *j*, at *k* and, raising the piston and weight, shuts off steam by forcing down the throttle valve, *h*, the pressure of the lever being applied at the point, *l*. The governor may be adjusted to its work by the spring and thumb-screw, *m*, acting on the small lever *n*, which tends to keep open the throttle against the downward pressure of the weighted lever, *i*, upon the valve stem. The spring, *o*, is introduced to ease the drop of the weight when the air pressure falls.

Norwalk Pressure Regulator. In the main steam pipe is placed a balanced throttle valve, Fig. 32 a. Attached above this valve is a small air cylinder, *b*, the piston rod of which is a prolongation of the valve stem, *c*. At the side of the cylinder, *b*, is a spring safety valve, *d*, connected by a pipe, *e*, with the receiver, or with the air main leading to it. By means of a hand-wheel, *f*, on the safety valve the spring is adjusted so that the air will lift the valve, and pass through it, at any desired pressure. When the receiver pressure exceeds this limit the safety valve, *d*, rises and allows air to pass under the piston in the small cylinder, *b*, raising it and partly closing the throttle. If no escape were provided the piston would be forced at once to the top of the cylinder. To regulate its movement and prevent shutting off the steam completely, a very narrow verticle slot is cut in the side of the cylinder. As the piston rises more and more of this slot is uncovered and furnishes an escape for the air passing into the cylinder. The slot being very small a slight difference in the quantity of air causes the piston to assume a high or low position. In this way the throttle is moved, controlling the admission of steam and the compressor speed. As the air pressure falls the valve begins to open again. To prevent the small piston from rising too far and stopping the compressor by completely closing the throttle, a screw stop *g* is set in the top of the regulating cylinder, *b*. This can be so adjusted that just enough steam is admitted to turn the compressor over its centers. In a later form of the Norwalk regulator the slot in the side of the cylinder, *b*, is replaced by a slot in the stem, or piston rod of this cylinder, as shown by Fig. 33.

These regulators are simple and effective, but do not entirely provide for the case when, for a time, no air at all is being drawn from the receiver. The air pressure must then be relieved by

blowing off at the receiver safety valve, or else the compressor must be stopped by the engineer. This difficulty is met under ordinary circumstances by the regulator described below.

Ingersoll-Sergeant Regulator. A weighted safety valve, *a* (Fig. 34), is attached directly to the shell of the air cylinder. It has

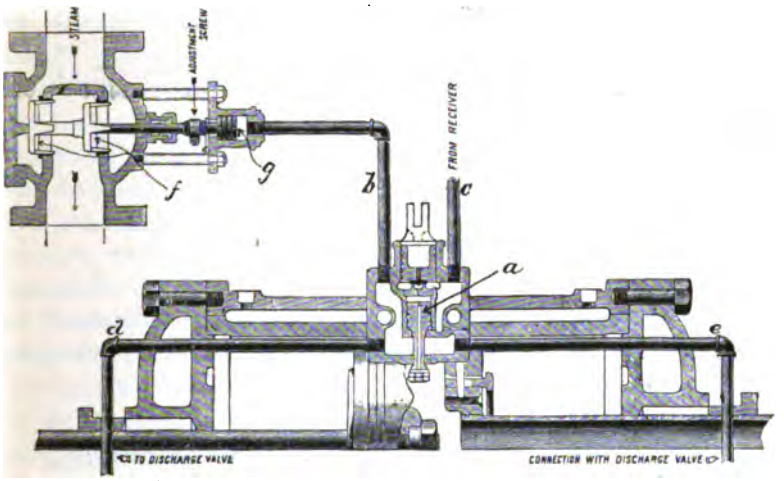


FIG. 34.

four pipe connections as shown: *b* leads to a balanced throttle valve in the main steam pipe, *c* connects with the air receiver, and *d* and *e* with two discharge valves, one at each end of the cylinder. The stem of the steam throttle, *f*, is a continuation of the piston rod of a small horizontal air cylinder, *g*, which is attached to the side of *f*. Behind the piston of this little cylinder enters the air pipe, *b*. When the pressure in the receiver becomes too great the safety valve, *a*, rises, and exhausts the air behind the two valves which are connected by the pipes, *d* and *e*. This admits air at receiver pressure into each end of the main cylinder, thus balancing the pressure on the two sides of the piston and unloading the engine. At the same time the air in the little cylinder, *g*, is also exhausted, so that the throttle valve, *f*, moves to the right and admits only enough steam to keep the compressor slowly turning. When the compressor is thus unloaded no work is done; the air is merely circulated through the pipes, *d* and *e*, from one end of the cylinder to the other, until more air is drawn from the receiver and the pressure reduced. Then the safety valve, *a*, closes and the pipes,

d and *e*, are again filled with compressed air. The steam throttle is also forced open by the pressure through the pipe, *b*, and compression goes on regulary. Fig. 35, though not an exact card,

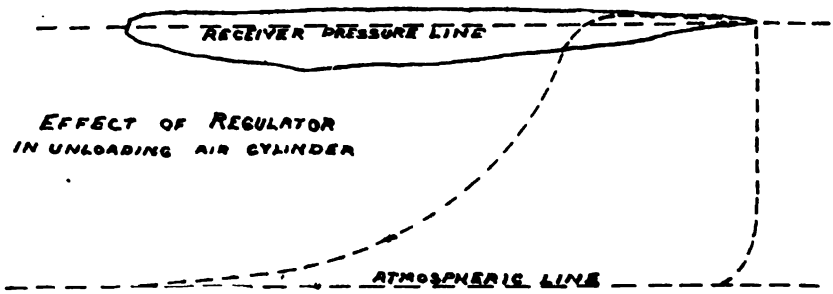


FIG. 35.

represents a diagram taken from the unloaded air cylinder of an Ingersoll-Sergeant compressor during the action of the air pressure regulator.

CONVEYANCE OF COMPRESSED AIR THROUGH PIPES.

Certain lossses due to friction take place in conveying compresssed air through lines of piping, and the proper diameter of the pipe is a matter of importance. These losses appear in two ways: as loss of pressure or head, indicated by difference in gauge reading at the ends of the line, and as loss of power.

First, for short distances the loss of pressure may be considered as taking place according to the laws governing the flow of all fluids, varying directly as the length of pipe, directly as the square of the velocity, and inversely as the diameter of the pipe. But for long distances the application of these laws becomes somewhat complex. In addition to the factors just given, it is necessary to take into account the volume and pressure of the air and the difference between the pressures at the receiver and at the end of the pipe line. All are more or less interdependent. The elements of the problem are well set forth in the following quotation:* "The flow of air being assumed to be uniform at the entrance to the pipe, the rate of flow is not constant for the whole length of the pipe, nor indeed for any point but the beginning of it. As the air may be said to carry in itself, in its elasticity, its own means of propulsion,

*Frank Richards, Compressed Air, p. 112.

some of which it is using as it goes along, it is constantly losing some of its pressure, and its volume is, therefore, constantly increasing. If the quantity of air entering the pipe is to continue to flow through it, the linear velocity of flow must be constantly accelerated on account of this increase of volume. This also modifies the use of the length of the pipe as a constant factor. It would be natural to assume, as in the formulas in general use it is assumed, that if a certain head were sufficient to maintain a certain flow for a given length of pipe, double the head would be sufficient for double the length. But that could not be so, for in the second length all the head that propelled the air through the first length has disappeared; therefore the volume is now greater through the loss of that pressure, and, as the velocity is also greater, it must require more additional head for the second length than was required for the first."

A similar course of reasoning applies to the question of diameter of pipe. The actual discharge capacity of piping is not proportional to the cross-sectional area alone—that is, to the square of the diameter. Although the periphery is directly as the diameter, the interior surface resistance is proportionally much greater in a small than in a large pipe, because as the pipe becomes larger the ratio between area and perimeter increases. To pass a given volume of compressed air a 1-inch pipe of given length requires over three times as much head as a 2-inch pipe of the same length. The character of the pipe, also, and the condition of its inner surface, have much to do with the friction developed by the flow of air. Besides imperfections in the surface of the metal, the irregularities incident upon coupling together the lengths of pipe must increase friction. Furthermore, each bend or elbow has its retarding effect.

The following formula for calculating the friction of air in pipes is given by Frank Richards, "Compressed Air," p. 115:

$$H = \frac{V^2 L}{10{,}000\, D^5 a}$$

D = diamete of pipe in inches.

L = length of pipe in feet.

V = volume of compressed air delivered in cubic feet per minute.

H = head or difference of pressure required to overcome friction and maintain the flow.

a = coefficient.

VALUES OF a FOR DIFFERENT NOMINAL DIAMETERS OF WROUGHT-IRON PIPE.

1″ . . . 0.350	2½″ . . . 0.650	5″ . . . 0.934
1¼″ . . . 0.500*	3″ . . . 0.730	6″ . . . 1.000
1½″ . . . 0.662*	3½″ . . . 0.787	8″ . . . 1.125
2″ . . . 0.565	4″ . . . 0.840	10″ . . . 1.200
		12″ . . . 1.260

Owing to the uncertain conditions under which air flows in pipes the results obtained from formulas are only approximately correct; the approximation is generally near enough for practical purposes, but there are so few reliable data that the influences by which the values of some of the factors may be modified are not fully understood. However, the loss of pressure in transmission is small as compared with other losses encountered in the compression of air and in its use, and may almost be neglected if piping of reasonable size be employed.

To obtain the best results the velocity of flow in the main air-pipes should not exceed 20 feet per second. By using piping large enough to keep down the velocity the friction loss may be almost eliminated. For example, at the Hoosac tunnel, in transmitting about 175 cubic feet of air per minute, at a pressure of 60 lbs. through an 8-inch pipe 7,150 feet long, the average loss was only 2 lbs. A volume of 78 cubic feet of air per minute, at 60 lbs. pressure, loses by friction 3.35 lbs. in passing through 1,000 feet of 3-inch pipe, but if the same volume be passed through a 6-inch pipe of the same length the loss of pressure is reduced to $\frac{104}{1000}$ lbs.

A due regard for economy in installation, however, must limit the use of very large piping, the cost of which should be considered in relation to the cost of air compression in any given case. Diameters of from 4 to 6 in. for the air mains are large enough for any ordinary mining practice. Up to a length of 3,000 feet a 4-inch

*The actual diameters of 1¼″ and 1½″ wrought-iron pipe are 1.38″ and 1.61″ respectively. Therefore, their values of a are not consistent with the values for the other sizes of pipe. Richards, p. 116.

pipe will carry per minute 480 cu. ft. of free air,* compressed to 82 lbs., with a loss of only 2 lbs. pressure. This volume of air will run six 3-inch drills. Under the same conditions a 6-inch pipe, 5,000 feet long, will carry 1,100 cu. ft. of free air per minute, enough for 13 drills. The table on following page, published in the catalogue of the Norwalk Iron Works Company, will be found useful.

A mistake is often made in putting in branch pipes of too small a diameter. For a distance of say 100 feet a 1¼-inch pipe is small enough for a single drill, though 1-inch is frequently used. In making short connections it is, of course, admissible to increase the velocity of flow considerably beyond 20 feet per second. Fig. 36 shows in a convenient form the relations between length of piping, volume of air and loss of pressure.†

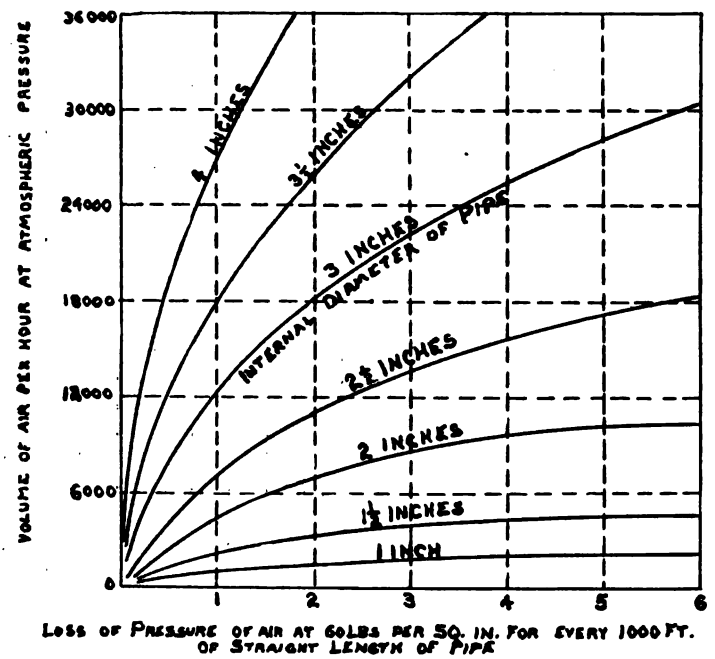


FIG. 36.

* "Free air" is air at atmospheric pressure. In most tables the volumes of air required for rock drills and other machines are given in terms of free air. Volumes of free air are easily converted into corresponding volumes of compressed air by dividing by the absolute pressure in terms of atmospheres. Thus, a volume of 600 cu. ft. of free air when compressed to 80 lbs. gauge pressure is reduced to $\frac{600 \times 15}{80+15} = 94.7+$ cu. ft.

† Goodman: Trans. Fed. Inst. M. E., Vol. VII., No. 2, p. 243.

Table IV.

Cubic Feet of Free Air Delivered in Compressed Form, at 80 lbs. Gauge Pressure, per Minute.

Nominal size of Pipe in inches	1		1¼		1½		2		2½		3		3½		4		4½		5		6		7		8	
Length of Pipe in feet	50	100	100	200	250	500	250	750	250	750	500	1500	750	2000	1000	3000	1500	3000	2000	4000	2000	5000	3000	10000	3000	10000
Gauge Pressure at the Entrance to the Pipe. 80.2	23.7	16.8	35.6	20.7	40.1	28.4	76.	49.	143	83	163	95	210	128	263	153	288	211	341	383	558	352	894	379	999	546
80.4	33.1	23.4	49.7	29.	56.	39.6	106.1	61.6	200	116	228	132	292	179	368	213	416	295	477	535	781	493	970	530	1397	763
80.6	41.1	29.	60.9	35.4	68.7	48.6	130.	75.5	245	142	279	162	358	220	451	262	506	361	585	656	957	605	1189	650	1712	936
80.8	47.	33 2	70 3	41.	79.3	56.	150.1	87.1	283	164	322	187	420	254	521	302	589	417	675	757	1105	699	1373	750	1977	1080
81.	52.5	37.1	78.7	45.7	88.7	62.8	168.	97.5	312	184	361	211	463	284	582	338	659	465	755	847	1236	780	1535	839	2210	1208
81.2	57.5	40.7	86.2	50.1	97.3	68.8	184.2	107.	348	202	397	229	507	311	642	370	721	511	829	930	1356	857	1685	921	2437	1326
81.4	62.2	44.	93.2	54.2	105.1	74.3	199.	115.5	375	218	428	248	549	337	690	400	781	552	895	1004	1464	925	1819	994	2619	1431
81.6	66.5	47.	99.7	58.	112.4	79.5	212.9	123.5	402	233	457	266	586	360	738	428	835	591	967	1074	1566	989	1946	1063	2802	1531
81.8	70.6	50.0	105.8	61.5	119.3	84.4	225.8	131.	426	247	485	282	622	381	783	454	886	627	1015	1139	1662	1049	2065	1128	2974	1624
82.	74.4	52.6	111.5	65.	125.8	88.9	238.1	138.2	449	261	512	297	657	402	826	479	934	661	1071	1202	1753	1107	2178	1190	3136	1714
82.2	78.1	55.2	117.5	68.3	132.	93.4	250.	145 1	472	274	537	312	689	422	867	503	1071	694	1124	1262	1840	1162	2286	1249	3292	1799

Second. Small as is the reduction of pressure due to friction, the actual loss of power is still smaller. This is so because the compressed air increases in volume as its pressure diminishes, thus producing a certain amount of compensation. The loss of head may easily be two or three times the actual loss of power. It is probable that in practice much of the power loss experienced is due to leakage from pipes. Air leaks are more expensive than steam leaks because of the losses already suffered in compressing the air. All joints in air mains and branches should be carefully made. To render the piping readily accessible for inspection and stoppage of leaks it should not be buried, but, if possible, carried in boxes; or, if underground, it should be supported upon brackets in the mine workings.

For long lengths of piping expansion joints are required, particularly when on the surface. Underground they are not required, as the temperature is usually nearly constant, except in shafts, or elsewhere, where there may be considerable variations of temperature between summer and winter.

Air mains may be of cast or wrought iron. If of wrought iron, as is cnstomary, the lengths are connected by cast-iron flanges into which the ends of the pipe are expanded or screwed. Wrought-iron spiral-seam riveted, or spiral-weld steel, tubing is sometimes used. It is made in lengths of 20 feet or less. For convenience of transport rolled sheets in short lengths may be had. They are punched around the edges, ready for riveting, and are packed closely, 4, 6 or more sheets in a bundle.

Freezing of Moisture Deposited from Compressed Air.

Reference has been made to the trouble sometimes caused by the congelation of the moisture carried in and deposited from compressed air. The air from wet compressors usually contains more moisture than that from dry compressors, though all compressed air carries some moisture. With dry compressors the humidity of the intake air largely determines the amount of water carried into the pipes. The capacity for the absorption of water of a given volume of air depends upon the temperature of the air. At a uniform temperature this capacity is constant, and for the same volume is independent of the pressure. But, if a certain amount of moist atmospheric air be compressed isothermally, say to $\frac{1}{10}$ of its original volume, its water capacity is also reduced to $\frac{1}{10}$, and $\frac{9}{10}$ of

the water originally carried in the air is deposited. Therefore, while the water capacity of a given volume of air varies with the temperature, it must change also with any increase or decrease of the pressure which changes its volume.

Certain conditions are required to cause freezing of compressed air: deposited moisture must be present, and must be subjected to a temperature below the freezing point. So long as the temperature does not fall low enough the presence of moisture can do no harm. Although one of the recognized functions of the air receiver is to permit the deposition of water before the air passes into the pipes, still, unless the receiver be extremely large, the air must leave it warm—sometimes even quite hot—and therefore carries considerable moisture with it. To prevent freezing all surface piping must be protected from frost. Otherwise the effective cross-section of the pipe will be reduced, or it may even freeze solid by the gradual accumulation of ice. The temperature underground is rarely low enough, except in winter in cold down-cast shafts, to make such protection necessary.

The foregoing naturally refers only to the effect of external cold during transmission upon the moist compressed air. For another reason, however, the air should be drained of water as completely as possible before it is used. When the air is finally expanded in the rock drill or air motor, intense cold is produced as the pressure falls and the latent heat of compression is absorbed. It is here that the moisture still remaining in the air makes its appearance as frost and causes trouble. Although the water in the pipes may be readily drained away under the proper conditions, the means for doing it are often neglected. The difficulty is effectually overcome by introducing an underground receiver near the machines using the air; that is, at the point where the pressure in the pipe has reached its minimum through frictional loss of head, and where the temperature of the compressed air has become normal. If the air main be led into such a receiver the water already deposited in the pipe is collected and may be drawn off at intervals.

At the Drummond Colliery, Nova Scotia, for running an underground pump by compressed air two receivers are used, one near the pump, and another 300 feet farther back on the pipe line. The air pressure in the main from the surface is 85 lbs., and as the portions of the cylinders of this particular pump are such that

so high a pressure was unnecessary a reducing valve was put in the pipe just before reaching the first receiver. By this valve the air is wire-drawn to reduce the pressure to 45 lbs., which results in a deposition of nearly one-half the entrained water, in addition to that already deposited in the pipes. It is found that more moisture collects in the first than in the second receiver, and by this device the serious difficulty previously encountered from freezing at the pump has been entirely overcome.* The temperature lost by the reduction of pressure to 45 lbs. is regained before the air reaches the pump.

It should be stated in this connection that, under ordinary circumstances, compressed air at a low pressure is likely to give more trouble from freezing than at high pressures, because a larger volume of air is required to do the same work in the motor cylinder, the lower pressure affords less opportunity for removing the moisture, and more water actually passes into the cylinder.† For the prevention of freezing the plan of carrying a very small steam jet over the exhaust port has been adopted, but obviously could be employed only when steam is used close by for some other purpose.

Using Compressed Air Expansively.

In machine rock drills the air is admitted to the cylinder practically throughout the full stroke. Expansive working is not advisable for drills because strength and simplicity of mechanism are of the first importance for machines subjected to such rough usage, and because of the difficulty of adapting cut-off gear to the variable length of stroke required. But when larger machines, such as underground pumps, hoists and other stationary plant, are operated by compressed air, greater economy is attained by using the air expansively; that is, by cutting off admission before the end of the stroke.

It is evident that when the air is used in this way, like steam, a large part of the loss of heat must take place inside of the cylinder, instead of outside at the mouth of the exhaust port. The same total fall of temperature occurs in either case, whether working at

* This information has been kindly furnished by Mr. Charles Fergie, Supt. of the Drummond Colliery. See also Mr. Fergie's article on the subject, in Transactions Canadian Mining Inst., 1896, of which an abstract was published in the *Colliery Guardian*, October 30, 1896, p. 821.

† Frank Richards, Compressed Air, p. 155.

full stroke or with cut-off. But, in exhausting at high pressure, as is done with rock drills, the exhaust air issues from the port at a high velocity, and its force, combined with the development of some heat from friction, in a measure prevents any troublesome formation of ice. It is confined at least to the exterior portion of the port, whence it is easily removed if neceesary. With expansive working, on the other hand, not only may considerable cold be produced inside the cylinder, but the force of the exhaust is diminished because of the reduction of pressure at the end of the stroke, and the inner portions of the ports are liable to be choked with ice. For this reason it is of much greater importance thoroughly to drain the air before use in engines where it is to be employed expansively than for rock drills. Underground receivers, valuable in any case as equalizers, become almost indispensable for such compressed air service.

The freezing-up of the motor cylinder may be prevented also by heating the compressed air just before use, or by heating the cylinder itself. The reheating of compressed air will be considered below.

There are several methods of warming the cylinder, though none of them are very convenient or successful. The cylinder may be jacketted by enveloping it with spiral hot-water or hot-air pipes, or by injecting hot water in small quantities. Sometimes the air cylinders of small compressed air pumps are warmed by lamps or torches, but this is objectionable, as the machines become extremely dirty. All such devices have some effect in increasing the duty of compressed air, because even a small degree of heat so applied raises the pressure, but they do not properly come under the head of appliances for reheating the air, nor are they used with that end in view.

Reheating Compressed Air.

It has been seen that after the warm compressed air leaves the compressor and receiver on its journey through the transmission piping its temperature is quickly reduced to that of the surrounding atmosphere. The loss thus caused could be prevented only by using the air immediately and before it has time to cool. The facility with which the heat of compression is given up, however, suggests that something might be gained by reheating the compressed air when it reaches the place where it is to be employed.

By such reheating an additional volume of air is produced at a much cheaper rate than if it were produced in the compressor itself. In a large plant at Paris only 0.2 lb. of coke has been consumed in reheating the air for an added production of 1 H. P., which is say about one-eighth of the fuel consumption of the best compressors. This result agrees closely with the theoretical figures given by Mr. Frank Richards in his book on Compressed Air, p. 159. But it must be remembered that to effect this saving the air must pass after reheating directly into the motor cylinder. A farther conveyance in pipes for even a very short distance rapidly lowers the temperature and pressure, so that reheating in mining operations has a limited application. For portable machines, like rock drills, it is economically out of the question. For stationary engines, however, such as underground pumps and hoists, and wherever the reheater can be placed close to the air engine, reheating becomes useful not only in increasing the efficiency of the compressed air, but in preventing freezing at the exhaust ports when the air is used expansively. In underground work it may be difficult to arrange for burning fuel under a reheater, notwithstanding the comparatively small amount of fuel required, because of the resulting vitiation of the mine atmosphere. Also, in gassy collieries reheaters cannot well be used, though sometimes the gases of combustion may be turned into an upcast airway, or even allowed to escape into the mine workings when the active circulation of large volumes of air is maintained.

The heat may be applied by passing the compressed air through a coil of pipe enclosed in a small furnace near the motor. As this coil forms a part of the air main, reheating can increase the *pressure* only in a small degree. Its real effect is to increase the *volume* of air, which backs up in the main, reducing the velocity of flow and, therefore, the loss of pressure due to friction. Another method of reheating has been proposed—that of placing in the air main an electric coil heater. This would do away with the difficulty of disposing underground of the products of combustion of the fuel, and would be specially useful in gassy collieries.* Occasionally, for large surface plants the device of compounding the motor cylinders has been adopted. The exhaust from the high-pressure cylinder is passed through another reheater before going to the low-pressure cylinder. A further advantage may be de-

* W. L. Saunders, *Engineering News*, August 25, 1892, p. 176.

rived by injecting into the reheater coils a very small quantity of water. The water is converted into steam, and on giving up its latent heat in the motor cylinder prevents freezing at the exhaust even when a very high ratio of expansion is employed. *

At a constant pressure the volume of air is proportional to its absolute temperature, or 459° F. plus the sensible temperature as read on the thermometer. The absolute temperature of air at 70° F. is 459 + 70 = 529°. In doubling the volume by the application of heat the absolute temperature becomes 1058°, and 1058 − 459 = 599°, which is the corresponding sensible or thermometric temperature of the air. On account of the rapidity with which air gives up its heat, this temperature is greatly reduced by the time it reaches the motor cylinder, where it loses still more heat before its work is done. To reheat the air to a temperature which would really double its volume *in* the motor cylinder would involve a temperature in the reheater much higher than 599°. But such temperatures cannot be employed, because they would render impossible the proper lubrication of the cylinder. If the temperature be raised by the reheater to 400° F. a loss of say 106° should be allowed for cooling before the air is actually used. The absolute cylinder temperature is then 300 + 459 = 759°, and the corresponding added volume of compressed air is found by the proportion.

$$529 : 759 :: 1 : 1.43$$

That is, there has been an effective increase of 43% in the volume of compressed air by heating in the reheater to 400°. It is improbable that a much higher temperature would be desirable.

Capacity of Air Compressors.

A standard of rating, useful for ordinary purposes, is the capacity in terms of cubic feet of free air compressed per minute to a given pressure. The expression "free air" means air at atmospheric pressure, as taken into the cylinder, and the theoretical capacity is found by multiplying the net piston area in square feet by the distance traveled by the piston in feet per minute. The actual capacity will be somewhat less than this on account of the various losses due to leaks, clearance, induction of warm air, friction of inlet valves, etc. In a properly designed compressor an allowance of 15% is sufficient

* Goodman: Trans. Fed. Inst. M. E., Vol. VII., No. 2, p. 245.

to cover these losses, which must not be confounded with the mechanical loss of work; that is, the work expended in overcoming friction in running the compressor.

Having found the capacity in terms of free air, the volume occupied by this air at any given pressure is calculated by Mariotte's law, represented in its simplest form by the expression: $V' = \frac{PV}{P'}$, in which P = absolute pressure of atmosphere, and P′ = absolute pressure of the air at any point of the stroke; that is, after the piston has traveled any given distance. It must be remembered that gauges register pressures above atmospheric pressure, so that P = gauge pressure + 14.7 lbs. (in round numbers 15 pounds). For example, 100 cubic feet of free air compressed isothermally to 65 lbs. gauge pressure will occupy a volume:

$$V' = \frac{100 \times 15}{65 + 15} = 18.75 \text{ cu. ft.}$$

Conversely the volume of free air represented by 18.75 cu. ft. at 65 lbs. gauge pressure is:

$$V = \frac{18.75\,(65 + 15)}{15} = 100 \text{ cu. ft.}$$

By applying the allowance for losses, stated above, results are obtained sufficiently correct for practical purposes.

The capacity of a compressor may be stated, also, in terms of the horse-power developed by the steam end of the engine. The effective horse-power of the air delivered, however, must be calculated from an indicator card taken from the air cylinder. In considering an air card it should be observed that the various lines have a signification different from those of a steam card. They are reversed thus:

Steam Card.	Air Card.
Admission line.	Delivery line.
Expansion "	Compression line.
Back-pressure or exhaust line.	Admission line.
Compression line.	Re-expansion line.

The re-expansion line in an air cylinder is the pressure line resulting from the expansion of the air filling the clearance space.

Compressors for mine work are usually roughly rated as furnishing sufficient air to operate a certain number of rock drills. A 3-inch drill requires a volume of air at 60 lbs. pressure equal to 80 or 90 cu. ft. of free atmospheric air per minute.

Air Compression at High Altitudes.

Because of the diminished density of the atmosphere at high altitudes air compressors do not give the same results in mountainous regions as at sea-level. For example, a compressor furnishing, at the atmospheric pressure of 15 lbs., 872 cu. ft. of air at sea-level, will produce only 722 cu. ft. at 6,000 ft. elevation, and 634 cu. ft. at 10,000 ft. The following table shows the reduction of efficiency, at various elevations, for a gauge pressure of 60 lbs:

Table V.

ELEVATION IN FEET.	BAROMETRIC PRESSURE.	EFFICIENCY.
0	30.00	1.000
1000	28.85	.969
2000	27.78	.940
3000	26.74	.911
4000	25.70	.881
5000	24.73	.859
7000	22.93	.802
8000	22.04	.775
10000	20.43	.727
12000	18.92	.680

The volume of compressed air produced at a given altitude may be found by multiplying its capacity at sea-level by the percentage efficiency in the third column above.

Although somewhat less power is consumed in running a compressor above sea-level, still the required horse-power is not decreased in a degree corresponding with the reduced capacity. The disadvantages of ordinary poppet valves, controlled by springs, increase as the atmospheric pressure diminishes, because such valves must open later in the stroke than when at sea-level. It is found that compressors using same form of mechanically controlled inlet valve are well adapted for work at high altitudes. Some builders make the air cylinders for mountain work proportionately larger for the same size of steam cylinder, but the net result is that at high altitudes compressed air costs more than at sea-level.

Efficiency of Production and Transmission of Power by Compressed Air.

In calculating the efficiency of the production and transmission of power by compressed air several losses are to be taken into account. The following estimate is for a gauge pressure of 75 lbs.

1. The mechanical loss due to the friction of the moving parts of the compressor. This ranges from a minimum of about 5%, in large, tandem compressors with Corliss valve gear, up to say 15% in some of the smaller machines. The friction loss in ordinary straight-line compressors, in good order, may be taken as 10%.

2. The loss of energy in the work of compression, due to the heating of the air. This loss is represented by the difference between the actual mean effective pressure in the air cylinder and the pressure that would be required for isothermal compression. It is rarely less than 15%.

3. Several losses may here be grouped under one head, caused by the heating of the intake air by the hot metal surfaces in the cylinder; clearance; friction of valves, and leakage at piston and valves, amounting in all to, say, 12%. A further preventable loss would result from the induction of warm air from the engine room.

The sum of these losses leaves a total net efficiency for the compressor of:

$$90 \times 85 \times 88 = 67+ \%,$$

which may be considered as representing good average work. In compound (two-stage) compression the efficiency may be somewhat higher. Under the best conditions, where the friction loss is as low as 5%, and the other losses are cut down slightly, the efficiency may reach in the neighborhood of 75%, rarely higher.

Losses in the Transmission and Use of Compressed Air. 1. The loss caused by friction and leakage during transmission in the piping needs not exceed 3% or 4% in ordinary mining practice.

2. The loss due to imperfect final expansion in the cylinder of the machine using the compressed air is usually a heavy one. It is the difference between the work actually done and that which is theoretically obtainable from the air. If perfect expansion in the motor cylinder were possible the only loss here would be that caused by friction of the mechanism. But this is never realized

even under the most favorable conditions. In all rock-drills, and in many pumps and other air engines, there is no attempt to use the air expansively. In a drill the work is done by *pressure* of the air only, final expansion taking place after exhaust. Ordinary direct acting pumps, also, when they are run by compressed air take the air as they do steam, throughout the whole stroke. Upon the whole, the work of compressed air drills and pumps, in common mining practice is done at a motor loss of from 40% to 50%.* This is apparently a poor showing, but is not at all unusual.

The sum of all the losses, as above, leaves a net efficiency of 67 (compressor) × 96 (transmission piping) × 60 (air engine) = 38 + %. This should be considered fairly satisfactory work. Taking the motor loss as 50 % (which is probably not far from the truth at least so far as pumps are concerned), the efficiency becomes 32 %. By reheating the air and using it in a properly designed engine, the total efficiency of the system may be raised to 50 %, or perhaps even more, but it is safe to conclude that no such result is attainable at present in ordinary mining operations. In part first of this article reference has been made to what appears to be an unavoidably wasteful use of air in rock drills. They are, notwithstanding, fairly satisfactory machines, and whether or not they are economical in their consumption of air is, under the circumstance, really a matter of secondary importance. With underground pumps the case is different, and there is room for great improvement. Although to the present time compressed air has not been much used for mine pumping, its great convenience for such service is unquestionable, and the subject should receive the attention of mechanical engineers.

Air Compression by Direct Action of Falling Water.

Although this method of compression involves no new idea, it has been only recently successfully carried out for producing large volumes of compressed air. During 1896 the Taylor Hydraulic Air Compressing Company, of Montreal, Canada, erected a plant embodying the system for the Dominion Cotton Mills, Magog, Province of Quebec.† Where the conditions permit its introduc-

* Zahner, Transmission of Power by Compressed Air, p. 97. Saunders, *Engineering News*, August 25, 1892, p. 175. Goodman, Trans. Fed. Inst. M. E., Vol. VII., No. 2, p. 244.

† The following description is based upon an article in the *Canadian Engineer*, March, 1897, and information furnished by the builders. See also *Engineering and Mining Journal*, Dec. 26, 1896, p. 606.

tion it promises to be useful for mining operations also. The air is compressed directly by water power, without the use of moving parts.

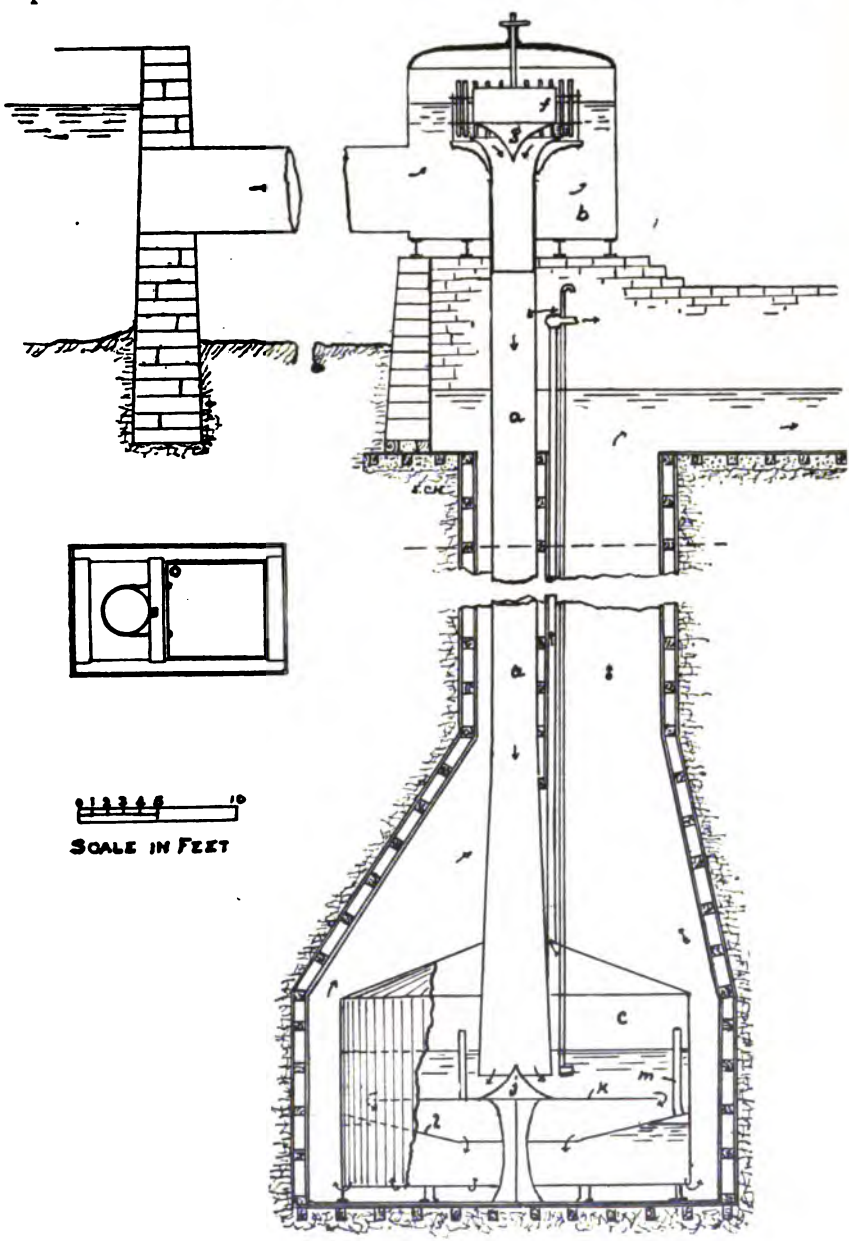


FIG. 37.

A shaft (Fig. 37) is sunk to a depth necessary to give the desired pressure, and in it is placed a large vertical compressing pipe, *a*. This pipe passes through the bottom of an iron receiving chamber, *b*, on the surface, to which water is conducted from a dam or reservoir. Water flows into and fills the pipe, which extends nearly to the bottom of the shaft. By means of an arrangement of small pipes described below, air is drawn into the vertical pipe with the water and is compressed while being carried down the shaft. The compressed air collects in a separating chamber, *c*, at the bottom of the shaft, while the water is returned to a tailrace near the top, giving in the Magog installation an effective head

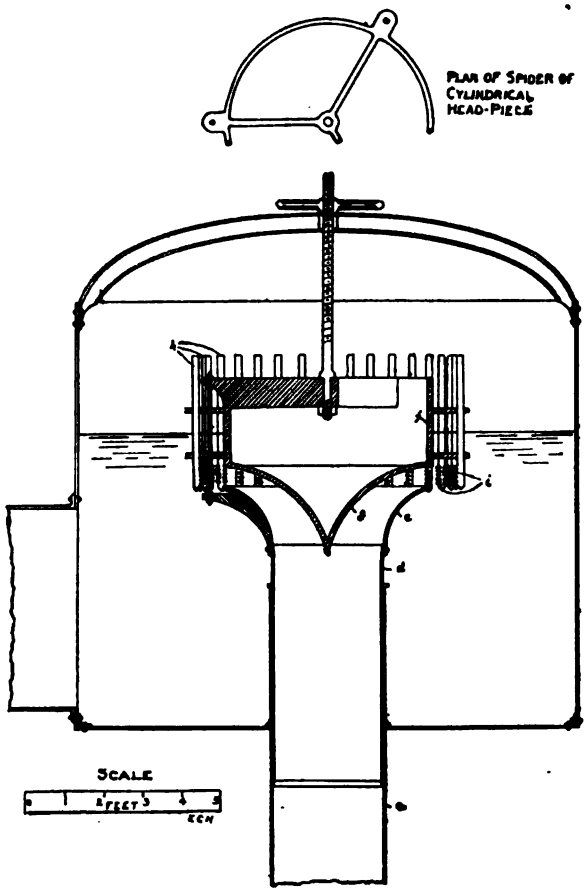


FIG. 38.

of about 22 feet. Into the top of the vertical pipe is inserted a telescoping section of pipe, *d*, to the upper end of which is riveted a bell-mouth, *e*. Above the latter is a cylindrical headpiece, *f*, (Fig. 38), terminating below in an inverted conoid, *g*, projecting into the bell. These two parts are connected by lugs and bolts in such way as to leave an annular opening between them, through which the water enters the vertical pipe. Around the headpiece is set a series of 2-inch pipes, *h*, *h*, open at the top and closed at the bottom. Into each of these pipes, near their lower ends, are screwed a number of short horizontal ⅜-inch pipes, *i*, *i*, all directed into the annular opening at the bell mouth and towards the center of the main pipe. As the entering water passes among the small pipes a partial vacuum is created in them, so that the atmospheric pressure drives the air into the water in the shape of small bubbles. These are carried with the water down the main pipe, and on their way are compressed.

Near the bottom of the shaft the vertical compressing pipe enters the large circular "separating" tank, *c*, open below and supported upon legs which raise it above the shaft bottom. Within the tank and directly under the pipe is the "disperser," *j*, a conoidal casting like the one in the headpiece. Plates, *k*, are are added around the periphery of the disperser to give it a larger diameter. Below is a conical apron, *l*, riveted to the interior of the separating tank. When the water, charged with air bubbles, reaches the disperser it is directed outward toward the circumference; is then deflected by the apron toward the center under the disperser, and finally escapes through the open bottom of the separating tank into the return column. During this process of travel the compressed air separates from the water, most of it collecting in the upper part of the air chamber. A portion of the air is not liberated until the water reaches the lower part of the tank, under the apron. Here it collects in the annular space and joins the main body of air through the pipe, *m*. The compressed air collecting in the top of the air chamber is kept under pressure by the weight of the return water column in the shaft. As the small air bubbles are constantly surrounded by cold water, it is evident that by this system isothermal compression is attained, with its corresponding advantages in minimizing the amount of moisture carried in the air. This has been shown by tests.

The shaft at the Magog mills is 128 ft. deep, and the air pressure

52 lbs. per sq. in. It is stated that the plant has been running successfully since September, 1896. Its efficiency is shown by the following table* to be from 50.1% to 62.4 %, according to the quantity of water used:

TABLE VI.

No. of test.	Quantity of water discharged, in cubic feet per minnte.	Available head in feet.	Available horse power.	Quantity of air delivered, in cubic feet per minute at atmospheric pressure.	Pressure of air, pounds per sq. in.	Actual horse power of Compressor.	Efficiency of Compressor, per cent.
1	6122	21.4	247.7	1377	52	132.5	53.5
2	5504	21.9	228.0	1363	52	131.0	57.5
3	4005	22.3	168.9	1095	52	105.3	62.4
4	7662	21.1	305.9	1616	52	155.4	50.8
5	6312	21.7	260.0	1506	52	144.8	55.7
6	7494	21.2	299.8	1560	52	150.2	50.1

Temperatures during tests: external air 75° to 83°; water 75.2° to 80°; compressed air 75.2° to 80°.

The parts were not correctly proportioned in this first installation, and there is no doubt that the efficiency could be considerably increased by using a relatively larger air chamber at the bottom of the shaft, to prevent air from going to waste. As shown by the table, the efficiency is increased by diminishing the volume of inlet water, upon which depends the quantity of air carried down and compressed.

In building a plant to produce higher air pressure the motive head, or difference in level between the surfaces of water at inlet and tail-race, would be increased. The theory is as follows: The combined specific gravity of the mixture of air and water in the vertical compressing pipe is less than that of the water in the return column. That is, the weight of water in the compressing pipe is less per foot than in the return column. Therefore, the head required, to overcome friction and to produce flow, must be greater

*Tests made by Prof. C. H. McLeod, of McGill University, August, 1896. Published in *Eng. and Min. Journal*, December 26, 1896, p. 606.

than if the apparatus were merely an inverted siphon, and as the difference in weight increases with depth (and air pressure produced) a constantly increasing motive head must be provided.

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NOTES ON THE PRESENT WESTERN PRACTICE OF METALLURGY—ECONOMICALLY CONSIDERED.

By W. B. DEVEREUX.

President Low has invited me to occupy a few hours in discussing with you some of the aspects of Western metallurgy. In undertaking to comply with this invitation, I am in doubt as to what method will enable me to utilize your time to the best advantage. My task is both easier and more difficult for the reason that you have already gone over so much of the subject; easier because it enables me to avail myself of the information you have already acquired; more difficult because I wish to avoid the repetition of what you already have at your command. The field from which I am to select my subject-matter is, however, very extensive, and one in which great activity prevails. Much of the recent progress has not yet been recorded in available form, and even in the recent metallurgical literature, there is much which needs the test of practical knowledge and additional experience before it is entitled to a permanent record. Moreover, apart from its technical side, Western metallurgy involves many factors contributing to success or failure which are hardly entitled to a place in the literature of the subject. It seems to me desirable, therefore, to first occupy a portion of your time with some general considerations and afterwards to outline some of the more recent metallurgical tendencies and practice. After all, much that I shall say to you will probably have a familiar sound; for, although modifications of both processes and appliances are constantly being introduced, radical innovations are seldom made, and even then gain a foothold only by degrees. Economical considerations should furnish the motive for introducing variations in practice, and unless these stand the test of the balance-sheet, they have no place in commer-

cial work. At the outset I wish to emphasize the fact that metallurgy cannot be mastered either in the class-room or with books. Together these will enable you to learn what processes are in use for the extraction of metals from their ores, and to obtain a knowledge of the various devices by which these processes are carried on; but that particular knowledge, so difficult to define, which I may term "the how" to do things, is something which you must acquire by actual practice. Do not, however, let the realization of this fact discourage you, for equipped with a general knowledge of the theory and practice of metallurgy, you can take up practical work under conditions which will enable you to grasp the details of practice rapidly and with intelligent understanding. There is no art to which the same reasoning does not apply. Theory must always be supplemented by practice. The doing of the thing always differs by indefinable variations from the description of how it is done, and new problems never comprise exactly the same factors as those already solved.

To illustrate: Suppose you were to go into a metallurgical works and take up your position near a blast furnace. After you had watched its operation for half an hour, you would conclude that the whole process was apparently a series of simple operations repeated at regular intervals. You would see the man at the top of the furnace charging the ore mixture, the calculations of which would present no especial difficulty. At the bottom of the furnace you would see slag being drawn off at intervals and at other intervals the metallic products. The whole cycle of operations would proceed regularly and without interruptions or miscalculations. If you were to go away after watching these operations for a short time you might possibly think that you had seen the whole of a blast furnace smelting. But suppose you were one of the staff of workmen actually operating this furnace, and you were compelled to spend eight or twelve hours a day in doing these very things that you have already seen. Sooner or later a time would come when the furnace would begin to work irregularly and fail to perform its regular functions.

The assays might show that the slag contained excessive quantities of valuable metal; the melted products might become cold and fail to flow properly; tapping might become difficult; the charge might descend irregularly or become too hot on top. At such times as these, if you were one of the working staff, you

would at once find yourself in a most valuable training school. The reasons for the special trouble would be determined, and you would assist in the application of the remedy, your scientific knowledge enabling you at the same time to understand the reasons for whatever action was taken.

In a few months, in all probability, almost all of the accidental difficulties which arise would have come up for a solution, and your knowledge of the same would have become comprehensive and available. There is nothing more necessary to the metallurgist and nothing which gives him more satisfaction than the ability to diagnose irregularities, and to correct them quickly and surely. There is nothing which so completely enables him to command the respect of his men and their best services as the ability to show them what to do and how to do it.

My advice to you, therefore, is to lose no opportunity to gain practical experience and, wherever you are, make it your first business to learn how to do everything and to be able to take the lead even under the most difficult and trying circumstances. The time which you spend watching ordinary commonplace operations, which are going on from day to day at any works with which you are connected, is never lost and will give the most valuable experience which you can acquire. It will round out your theoretical knowledge, put you in touch with the little niceties of your profession, and give you that intuitive perception which can only come from close observation and practice.

As a rule, only a few metallurgists in the West are able to devote themselves to metallurgical problems pure and simple. It is only in the large custom smelting works that they are relieved from business transactions and have only to concern themselves with the purely scientific side of the problems which come up for solution and, of course, it is these great establishments which afford the best opportunities to make improvements and to try experiments looking toward improved processes. Western metallurgy has for its object the treatment of ores produced in the great mountain region between the Western plains and the Pacific coast which reaches from the Arctic regions down through the United States and Mexico. It may be truthfully said that the ores from all these regions come to one or the other of the various metallurgical establishments in the United States and, in addition to these, in the past few years large works have been established in Mexico

and in the British possessions on the north. Ores of every possible description come to these works, but it by no means follows that these ores are all treated at the works nearest the mines which produce them. In nearly all of the smelting works of this country you will find that ores are constantly coming in from distant regions, owing to the fact of the particular works in question being able to pay a higher price than works nearer at hand. This is due to the fact that a given ore may supply a desirable ingredient for one locality and at the same time be undesirable or unnecessary at another.

A knowledge of metallurgy and metallurgical conditions is necessary for every mining engineer. The two professions of engineer and metallurgist almost invariably overlap in the West, especially in remote districts. The conditions vary so much even in localities near together that the determination of the proper metallurgical treatment of any ore becomes a problem of the greatest nicety. Of course, where mines are within reach of large custom works; the metallurgy of the mine is of little importance, although the mine manager must know the value of ores from a smelter's standpoint in order to so mine them as to obtain the best returns. But there are thousands of mines which are so far distant from metallurgical centers that the questions of transportation preclude the shipment of ores, except where the values are very high and hence local treatment becomes a necessity. Those who are called upon to pass upon these problems and to carry out the plans ultimately adopted must have not only a knowledge of general metallurgy, but of a thousand other things which are no part of metallurgy itself. In fact, there is very little information which will not, sooner or later, be found useful.

Suppose you were to consider the possibility of smelting an ore at a distance from the railroad in one of the Western deserts. One of the first requisites to determine would be the available supply of water. There might be available a stream which would contribute no water in the dry season and a flood in the wet. Storage reservoirs might therefore be a necessity, and this would involve extensive engineering knowledge. Long distance pumping might be a necessity from which would arise another set of problems.

There might be an underground current in the bed of the stream in the dry season which would furnish the necessary water, and this could only be determined by sinking wells. The available

supply of timber and its suitability would be another factor, also the relative costs of coke, coal and charcoal. If fuel was to be brought in by rail, your knowledge of railway conditions might materially affect the rates of transportation ultimately decided upon. At the same time, the question of wagon transportation would determine an important proportion of the total costs of fuel and, in addition, the cost of getting the product of the works to its destination.

It would hardly occur to you as a first experience that the fact of grass growing along the line of your wagon road and being available throughout the year might determine the question as to whether ore could or could not be smelted at the mine in question, or that the price of hay and oats might determine the amount of profit or loss. And yet, just such conditions as these are determining to-day the profit and loss account of active mining operations. The reason of this is very simple. If grass is available for feed, freighting can be done with oxen which are turned out at night to graze. If no grass is available, hay and grain must be fed, and the price of freighting is correspondingly greater.

The treatment of ores in the West comprises a few type processes upon which are based innumerable variations. Smelting, amalgamation and lixiviation, alone or in combination, are the general methods by which nearly all ores are treated. The selection of the method and its minor variations must depend on local conditions. In a general way smelting may be said to have superseded all other processes where suitable fuel can be obtained at a reasonable price, where transportation facilities are satisfactory, and where sufficient lead or copper can be obtained to collect the precious metals in the ores which are available for treatment. Many ores, however, require a preliminary concentration to provide a product suitable for metallurgical operations. The great advantage in smelting is due to the fact that the percentages saved are almost universally higher than by any other method and, therefore, as the ore increases in value the total saving becomes greater, and the disadvantage of freight charges and perhaps even a higher treatment cost is overcome. For instance, the Cripple Creek district in Colorado produces large quantities of high-grade ore running from fifty to several thousand dollars per ton, and also immense quantities of so-called "low-grade" ore averaging from ten to twenty dollars per ton. Although there are very large chlorination and cyanide establishments that are amply capable of buy-

ing the Cripple Creek ores, very little high-grade ore is treated in these, the smelters being able to command the market, in spite of the fact the ores are essentially quartzose and have to be provided not only with lead or copper for the collection of the gold, but also with a considerable amount of iron and lime for flux.

The smelting industry of the West comprises two distinct branches: namely, lead and copper smelting. In the first, lead is used as a collector of the precious metals, the conditions being such that the smelting of ores containing lead only has so far not proved commercially profitable. Owing to the fact that almost all ores of the precious metals carry some copper, the treatment of that metal has also become a subordinate branch of lead-silver metallurgy, and in recent years the copper obtained as a by-product has become an important item.

Copper smelting includes the treatment of ores which contain only copper, and also those which contain both copper and precious metals.

Lead-Silver Smelting.

Lead-silver smelting is an important industry in the West, and is carried on both by mining companies with their own ores, and by custom smelting works which purchase their ores in the open market.

Wherever the conditions are favorable this method has done away with the necessity for other metallurgical processes, except in the case of low-grade gold ores, these still being more economically treated by amalgamation or lixiviation.

Custom works are generally located at large railroad centres where coal and coke are abundant and cheap, and where ores can be drawn from a large extent of country, thus enabling smelters to purchase ores of every variety and in such quantities that the amount of barren flux added to make a smelting mixture shall be minimum. They offer great advantages to mine owners in that they purchase ores for cash upon an agreed basis and obviate the necessity for individual works at the mines. Moreover, there are very few mines the product of which is of such a character that it can be smelted by itself, the general condition being that large amounts of barren flux must be added, or the mining company must itself become a custom smelter, buying such ores as will suffice to make a smelting mixture when added to its own. As

the metallurgy in both instances is carried on under practically the same conditions, I shall endeavor to give you a résumé of the best smelting practice of to-day, and also to show you in what direction changes and improvements are being made, and to what ultimate results metallurgists are striving to attain.

In both custom and mine smelting works the first requisite is a sampling works of sufficient capacity. In order to accomplish good work it is absolutely necessary to know not only the value in precious metals of the ore which is to be treated, but also to have a complete analysis of its earthy or non-valuable constituents. Of course, in a private smelting works the only object in running the ore through the sampler is to determine its value and slag constituents. It is of the utmost importance that accurate and full details in regard to the ore be kept in books arranged for that purpose. In no other way can the metallurgist check the work that he is doing in his smelters, and in no other way can he so make up his ore mixtures as to obtain uniform slags. The ordinary form of book will show the ounces of Silver and Gold; the percentages of Lead and Copper and, in additional columns, the Silica, Iron, Lime, Magnesia, Baryta, Alumina and Zinc. The works should be charged with a total of the valuable constituents, even though the quantities are so small in some ores that they are not paid for, as is the case sometimes with small percentages of Lead, Copper, Silver and Gold. They are also credited with the amounts of valuable metals obtained and, at convenient times, a balance is struck and the percentages of values saved is determined, proper allowances being made for values in by-products, flue dust and in furnaces.

Sites for smelters should be so selected that there is ample room for the storing of ores in bins and for making up large beds of ore by distributing each lot in a layer on the bed as it comes in. As the charges are taken by shovelling from the face of the bed, a very fair mixture is obtained and the additional fluxes are added at the furnace, together with special kinds of ore, such as galenas and rich silver ores which may not be desirable to place in the beds. You will readily see that the analysis book showing the quantity of each lot of ore which has gone into the bed will furnish all the data necessary to calculate the total quantities of the valuable metals and the slag constituents, and that from these data the percentages or each per ton can readily be calculated. The metallurgist will then calculate the necessary additions to make whatever slag is desired.

There are certain type-slags which are considered more desirable than others, but the metallurgist will find in practice that he can often only approximate these, his constant effort being to make a good metallurgical slag with the least possible addition of barren flux or of non-profitable ores, the latter being ores purchased on a basis which either gives no profit or shows a certain amount of loss, in order to flux other ores on which the smelting charges are higher and from which the profits must be derived for both classes.

I shall only call your attention to a few points in regard to slags, as these have already been considered in your lectures and are discussed at length in your text-books. Thebest slags technically are not always the best commercially. Sometimes it costs more to make a good slag than a relatively poor one. In custom smelting the most refractory ores pay the highest charges and therefore that slag which will permit the use of the greatest amount of these ores is the most desirable up to the point where the losses in smelting balance the corresponding gain in smelting charges. Either lime, iron or silica may be expensive to flux under different conditions. Barite and zinc were formerly the bugbears of smelters, but are now permitted to a considerable extent, in fact cannot often be avoided. There is ample evidence to show that barite diminishes the loss of lead in the slag, though it is difficult to say just why it does so.

Lead and silver smelting less than twenty years ago was a very simple process as compared with the same process at the present time. Smelting was then carried on chiefly with surface ores already oxidized by natural causes and containing no deleterous ingredients. The furnaces were small, slags were easily made, and the smoke and dust was allowed to escape into the air. Very little matte was made and large percentages of lead were used in the charge. At the present time the easily smelted surface deposits have been exhausted to a large extent; the ores have become complex and carry sulphur; lead ores have become scarce and in great demand, and the percentage of lead used to collect the precious metals has steadily decreased. The presence of sulphide ores also necessitates roasting furnaces. Large quantities of matte are made, and the treatment of this matte has itself become complex because nearly all of the custom ores carry small quantities of copper which ultimately finds its way into the matte.

This has brought about the introduction of copper-metallurgy into lead-silver plants, and there are scarcely any custom works of this character in the West which do not have appliances devoted to the metallurgy of copper. So far as the theory of smelting is concerned, to a very large extent your knowledge of it will depend upon your thorough acquaintance with the conditions under which slags are formed and the chemical reactions of sulphur, oxygen and carbon with each other and with metals under metallurgical conditions.

These reactions are often obscure and complex and present a wide field for investigation and research. Mechanical considerations at the same time introduce limitations to methods theoretically possible, and hence it is only with an accurate knowledge of both theoretical and physical conditions that failures and difficulties can be reduced to a minimum.

Many ores require a preliminary roasting, and the method of doing this is therefore important. You are already familiar with the different types of roasters, so it is not necessary to describe these individually. In general there are the hand-roasters, which are long, straight, reverberatory furnaces with a fire-box at one end in which the flame from the fire traverses the whole length of the furnace. The ore in these furnaces is fed at the cool end, ordinarily through a hopper in the top of the furnace, and is stirred by hand rakes, being gradually moved down to the hot end of the furnace, where it is discharged either through the bottom or from a side door. Mechanical roasters have been very extensively used in the last few years, but owing to the fact that lead ores require to be roasted as nearly sweet as possible, it has been found that their capacity is very much smaller when used for this purpose, and in many of the largest and most complete works hand roasters are not only now in use but are being constructed in preference to mechanical roasters.

In some works large Brückner cylinders with a very slow rotation are used with satisfactory results. Generally, however, lead smelters object to mechanical roasters on account of the greater construction cost, excessive repairs, and comparatively low capacity when a low percentage of sulphur is required in the roasted ore. In copper smelting the conditions are different and mechanical roasters are extensively used.

So far as Western practice is concerned the only furnace used for

ore smelting is the water jacket-shaft furnace. The great impetus to lead-silver smelting came with the discovery of the carbonate ores in Leadville. The first smelters used there were small round water-jackets. With the need for a greater capacity came the introduction of the rectangular furnace, the width being kept about the same and the greater capacity being obtained by increasing the length. Without carrying you through the various stages of development of the water-jacket furnace, I may say that there has been a constant effort to get more capacity, and that at the present time metallurgists are still striving to build furnaces which will give a greater capacity than those at present in use. It has been found, however, that there are limits to the breadth of the furnace, which is the distance between the tuyeres, and also to the blast pressure. Furnaces have been constructed which exceed the present types in both of these conditions, but the results have been such as to fix the breadth for the present at about 42 inches and the blast at 32 ounces maximum. The general type of furnace now constructed has an inside dimension at the tuyeres of forty-two by one hundred and twenty inches. Furnaces forty-two by one hundred and forty inches are running satisfactorily, and others being constructed of the same dimensions. The ordinary practice is to make the height sixteen to seventeen feet from tuyeres to top of charge. This is an advance of about four feet over the height of charge which is still in use at many of the works, and is necessitated by the increase of blast pressure now used. Some new furnaces are also being made with a height of 20 feet. Sixteen ounces is almost a minimum blast pressure now, and from twenty-six to thirty-two ounces is common.

Three types of rotary blowers are in use, and these are constructed so that pressures even higher than 32 ounces can be maintained if desired. Fan blowers are not used by Western smelters.

The general construction of furnaces has changed but little in the past few years, and from the drawings you will see that the type is one with which you are already familiar.

The increase in dimensions has, however, necessitated more massive construction, owing to the larger amount of material the furnace is to contain. The foundations are of the best. The wrought-iron plate which forms the bottom of the iron enclosure for the crucible must be absolutely tight and rest solidly upon the foundation, preferably upou a layer of cement. Let me caution you here

against using cast-iron plates for the under part of the furnace, as a slight crack will admit of the passage of melted bullion down into the foundation. I have known cases where tons of bullion have found their way into the foundation of the furnace through a hole not larger than a nail hole, and when the furnace was taken down it necessitated the excavation through the foundation and down into the clay below for eight or nine feet before the last of the bullion was recovered. Crucibles should be made of good fire brick well luted together, so as to prevent as little absorption of bullion as possible. Generally the jackets rise to the height of the bosh only. Above this the furnace is constructed of brick. Some metallurgists have advocated the construction of the whole furnace of water jackets. The only real advantage in this is the fact that zinc and other accretions forming on the sides of the furnaces can be much more easily barred off from iron than from brick walls. On the other hand is the liability of injuring the jackets in barring down, the necessity for increased water supply, and the regulation and care of the additional jackets.

The brick work is supported as before on I beams resting on iron columns at the corners, or by a combination of I beams with arched steel plates (Colorado Iron Works). Recent constructions are very much heavier and the brick walls supported are likewise much thicker—in some cases 34 inches at the bottom —the lining being of fire-brick with the ends forming the interior surface of the furnace. These massive walls resist the action of the heat and are not liable to distortion.

Water-jackets are used exclusively for the lower part of the furnace. These are made both of wrought iron and of cast iron. Wrought-iron jackets are generally made so that a single jacket forms one side of the furnace, while cast-iron jackets are made in sections. Both constructions have advantages. In case of a leak a single cast-iron jacket can be taken out and a new one put in very quickly without blowing out the furnace. The disadvantage of cast iron is its liability to crack. This objection, however, has been overcome to a large extent by making the castings very carefully, so that the thickness of metal is uniform throughout, and changing the form of lugs by which the castings are bolted together, so that strains will not break these off; consequently the use of cast-iron jackets has been increasing in the last few years. In some works cast-iron jackets have always been used to the ex-

clusion of wrought iron. The advantages of wrought-iron jackets are that there is no possibility of cracking that the whole side of the furnace can be formed of one jacket, and the life of the jacket if properly cared for is much longer than that of cast iron. If the water becomes low in the jacket and the iron becomes overheated, the sudden introduction of cold water will not cause a crack, and damages to the jacket can be repaired to a very considerable extent by patching on the inside. Very long jackets, however, become very much warped through the difference in expansion of the inside sheet and the outside sheet, and a very decided bow in the center is established, thus disarranging the interior shape of the lower part of the furnace. Of course, if the furnaces are built in inaccessible places where it is difficult to replace jackets, one would naturally choose wrought iron in place of cast iron; but where foundries are available cast iron is generally preferable, as a few extra jackets on hand will obviate the trouble which might come from a single jacket breaking down. The old style of jacket, and one which is still in use to a large extent, has for the admission of air a hole cast in the side of the jacket in which is inserted a galvanized iron tuyere pipe. At best the nozzles do not make a very close fit, and when they have been knocked around by the furnace men a few times it is impossible to make them air-tight. Melted slag also damages them to a greater or less extent. When it is desirable to lessen the pressure of blast or cut it off altogether on a particular tuyere in order to allow the other tuyeres to melt away slag obstructions, it can only be done by tying the sack so as to close it partly, or by taking out the pipe and blocking the tuyere opening. Of course in well regulated furnaces running under proper conditions these things are very seldom required, but, at the same time, it adds very much to the convenience of the furnace to be able to do them without trouble when they are necessary. If it is easy for a workman to make any such temporary changes he will be much more apt to do them promptly. This has led to the introduction of a number of tuyere connections which supply such conditions to a greater or less degree. The general form of these is a cast-iron box or pipe which is flanged and bolted by lug bolts to the side of the furnace so that by loosening two bolts it can be lifted off.

This tuyere box is attached to the main air pipe by a canvas pipe or by a rigid iron connection. Personally I prefer the latter. The

tuyere box is also provided with a valve either in front of the tuyere opening or in the upper part. Some forms have valves similar to a clack valve with two openings, one of which opens into the outer atmosphere and is closed by the pressure of the air holding the valve up against the opening. In case the pressure is stopped suddenly the valve drops and closes the opening into the air pipe and falls away from the opening into the air. This is for the purpose of allowing the gas which always comes back into the air pipes when the blast is stopped to pass into the outer air, and thus prevent the possibility of explosions, which are sometimes very serious unless proper precautions are taken. Another form of tuyere consists of one box carried around the furnace either in front of the tuyeres or above them and connected to the tuyere openings by close-fitting connections. In many works to-day the whistle of escaping air can be heard in many places, and I have no doubt that the leakage from these sources, if measured, would astonish many metallurgists who consider their works are running very satisfactorily. It certainly needs but little argument to show that constant leaks through which air is blowing at about two pounds pressure must use up in the aggregate a very considerable amount of power. Power costs money, and its loss through mechanical defects in construction is inexcusable.

Furnaces of the type I have described will smelt from sixty to one hundred tons a day according to the character of the charge together with the addition of a certain quantity of rich slags. These are added to recover their valuable contents, and also to make coarse material in the furnace, which helps to keep the fine ore from packing and scaffolding, and forms interstices for the passage of the blast. It also performs another function which is not so well understood. By this I mean that although slag cannot be melted without a considerable amount of fuel by itself, yet it is universally found that, given a charge of ore running with the least possible fuel, a very considerable amount of slag can be added to the charge without necessitating any increase of fuel. The probability is that the slag, being already properly proportioned and having been liquid, melts first and acts as a carrier for the unfused slag forming material in the charge. In other words it becomes first, let us say, more siliceous, in which form it is very corrosive as regards the bases in the ore and combines with them, when it again has a great attraction for silica. With a furnace of

this class running under ordinary conditions, a number of products will be obtained the disposal of which is a matter for careful consideration. By far the largest product is of course the slag. In the earlier smelting practice in this country the slag was tapped directly from the furnace into iron slag pots which were wheeled to the edge of the dump and the slag immediately emptied out. It was found, however, that in tapping directly from the furnace a certain amount of metalwas carried out in the current of slag, and in addition, when ores were smelted which contained sulphides, a certain amount of matte was formed which was also tapped out with the slag. When no matte was present the metal tapped out with the slag could generally be saved to a large extent by pouring out the liquid slag and saving the partially cooled shell adhering to the sides of the pot. As soon as the matte became a factor in smelting it was necessary to allow the slag to cool in the pots and afterward the button of matte found at the bottom of the cone of slag was broken off and saved for subsequent treatment. This, however, rendered it impossible to save the shells, which were found to be of considerable richness, as the partially cooled slag on the sides of the pot prevented the small globules of matte and metal from settling. The next step consisted of having pots with a hole bored in the side above the height to which the matte ordinarily extended, and after the slag had sufficiently settled it was tapped out through this hole, leaving the rich shell on the sides of the pot and the matte in the bottom. This process is used in many works today, but it has the disadvantage of making more shells ordinarily than are required as a flux for the ore charge. Besides, it entails considerable labor in separating the matte which is more or less mixed with slag and not in as good condition for retreatment. The most feasible way to separate the matte and make clean slags is, by using a forehearth, and this device is now coming into extensive use in lead smelting. With the small furnaces formerly in use the forehearth was hard to manage, as it gradually crusted up, owing to the lack of sufficient hot slag to keep it heated up to the melting point. With the introduction of larger furnaces, especially those of 80 to 100 tons capacity, it has been found practicable to use forehearths which collect the matte, and from which the settled slag overflows into pots.

With coppery ores I have used a forehearth to collect both the matte, slag, and lead, and found it to work very satisfactorily, except

for the disadvantage of cooling too rapidly, to which I have called your attention, and even then it worked more satisfactorily than the old method of separating the lead inside of the furnaces. If lead furnaces could be constructed to run satisfactorily with a capacity of 200 tons a day, I have no doubt that the forehearth could make a very complete separation of clean matte and clean slags, and at the same time make long campaigns. I have recently seen in a lead furnace a forehearth after the Orford plan being used, which, as you know, is a rectangular box divided by a brick partition with an opening between the two compartments at the bottom of the partition. The matte and slag flow into one compartment and separate by gravity and the matte rises in the other compartment and overflows from a spout about two inches lower than the slag spout, the slag flowing out from the spout in the first compartment. This was, however, supplemented by the addition of another pot to catch any small grains of matte carried over in the current of flowing. The best method of disposing of slag is by granulation in a current of water which carries off the slag and deposits it at some point below the smelter. Where water is available this is very much the best method in use, and brings about a great saving in labor and cost. The slag is simply allowed to overflow from the forehearth into a trough with a rapid flowing stream of water and is immediately granulated and carried away to any convenient point. Where water is not available the present practice in large works is to use the Nesmith slag trucks. As you know, they consist of two large pots on a truck, so arranged that they can be swung out to the side and dumped on the outside of the track. The track for this is placed along the edge of the slag dump, and is moved out as the dump extends. In some works the slag is tapped or poured from the pots into these slag trucks. In others it is poured into very large pots, from which the slag is tapped from the side, and the matte tapped subsequently from the bottom. In others the slag empties directly from the forehearth into the bowl of the truck. The ideal method for separation would be to have the slag flow from the forehearth into water, or directly into large trucks, the matte being either tapped from the forehearth or allowed to overflow. In Rhodes' method the slag and matte from several furnaces are poured into a reverberatory furnace which is in effect a heated forehearth.

It is found that even with the siphon tap for lead a certain

amount of lead often finds its way out from the slag tap into the forehearth and this is obtained either with the matte or by tapping the forehearth at its lowest point. Of course the most valuable product of the furnace is the bullion, so-called, consisting of lead, varying amounts of silver, gold, and some copper, if copper is present in the ore. It is obtained by means of the well-known siphon tap, generally by dipping from the bowl, but in some works by means of a trough which swings over molds arranged on the circumference of a circle of which the trough is the radius. With this arrangement a number of moulds are filled at a time. Copper in lead ores in any considerable quantity often causes a great deal of trouble with the lead in the crucible, as it has a tendency to separate out in the form of a copper-lead alloy, which gradually cools and fills up the crucible, making it necessary to blow out the furnace and chisel out the crucible. As this alloy is very tough it makes the process very expensive. For this reason smelters do not like to have their lead mattes run over 10 per cent. copper.

The principal part of the copper should go into the matte which is a mixture chiefly of sulphides of lead, copper and iron. If this carries little copper it is simply crushed, roasted and put back into the furnace, furnishing iron for flux and giving up its valuable metals to the bullion.

In lead bullion carrying copper the copper is only paid for at the price of lead and, as it is worth three or four times as much, it is desirable to save it by itself. The present practice is to save the lead copper mattes, until a sufficient quantity has accumulated; roast them with sufficient heat near the discharging door of the furnace to make them slightly sticky, in which condition they are turned out of the furnace and allowed to cool. This agglomeration is simply to prevent them from being blown out of the furnace as dust. The roasted matte is smelted in furnace with a shallow crucible and with sufficient quartzose ores to flux the iron. If the proper mixture is made the lead will separate as bullion; the copper will combine with the sulphur left in the roasted matte, making a matte of from 45 to 70 per cent. copper, the iron combining with the silica and making a fusible slag. Twelve years ago I had to face the problem of the disposal of a very considerable quantity of these mattes carrying a large amount of silver where shipment was impossible. I was able, by running a basic iron slag, to make a very rich copper matte and to obtain a lead bullion carrying not over 5 per cent. of copper.

The last product of the furnace and one which is very annoying is the smoke and dust which pass out with the products of combustion. In custom smelting works the ore is almost all crushed to a very fine state for accurate sampling and for roasting, and the amount of flue-dust becomes a very considerable item and one that cannot possibly be disregarded. All well equipped furnaces, therefore, are provided with dust chambers, more or less extensive. These are of many and various types. Some are constructed of brick with hollow walls for cooling with a total length of passages as much as a mile. Others are constructed of sheet iron with a V-shaped bottom, the whole structure being enclosed to prevent condensation of acid fumes by cooling. The bottom of the dust chambers is provided with openings so that the dust can be drawn off at intervals into a car which runs on a track under the chamber. Another class which is used with very satisfactory results makes the final separation of the fume by filtering through cloth. One type of apparatus for this purpose is a house filled with long bags through which smoke is forced by a ventilating fan. These bags are shaken from time to time in order to keep the pores from becoming stopped with the dust, and the dust is taken out at intervals from the bottom of the sacks. A later invention than this consists of houses in which are sheets of cotton cloth stretched in tent-shape from the top. The smoke is forced through these and the tents are beaten at intervals with rods moved by a lever from the outside of the building, the dust falling to the floor. The disposal of the dust has been a very annoying problem. In some places it has been made into bricks with clay or with milk of lime either by hand or by machine. In other places it is immediately put into the reverberatory furnaces and heated until it slags together. The fume from the bag houses, however, is combustible and after a sufficient amount has accumulated on the floor of the house it is set on fire by throwing live coals on the surface at intervals. Apertures are opened to admit air and a gradual combustion takes place, sintering the mass together and forming a product something like coke, which is in the very best possible condition for treatment in the furnace. It has also been found that dust collected in the chambers before the smoke reaches the bag house is combustible and in some works this dust is simply piled in small houses with brick walls and set on fire. Air is admitted and combustion goes on until the

whole mass is sintered together. Smelting has now become subject to so much competition that there is an absolute necessity for saving all the values possible in the ore. Metallurgists who are working on ores from their own mines are often too careless about their losses, but it is just as reprehensible to lose values when you are working on your own ores, and with much larger margins for loss, as it is when you are working on custom ores where you are in competition with other skillful metallurgists.

I have used a method of blowing in lead furnaces which I think has sufficient novelty to merit a description. It starts the furnace off in good condition, and with ordinary care gives very little trouble.

The crucible is heated with cord wood and as soon as the walls are fairly hot a 2-inch pipe bent at an angle is inserted through the breast to the bottom of the wood fire and air is blown in. The crucible is filled with cord wood and, as soon as it is blazing well, several bars of bullion are shoved in on a plank and tipped off on the wood. This bullion melts and runs down through the hot fire to the bottom, becoming red-hot. This process is continued until the crucible is full of lead, when the fire is raked out and the lead thoroughly stirred up from the bottom and skimmed. The crucible and siphon are then full of red-hot lead perfectly clean. Brands and wood are then put back on the lead to form a support for the coke and to kindle it; the breast is put in and the furnace filled with coke to about 18 inches above the tuyeres; then light slag charges and coke to the top of the jackets; then charges part ore and slag and finally normal ore charges to the top.

A light blast is turned on until the slag begins to show at the slag taps and it can then be raised gradually to normal pressure. In this way the fusion zone is kept from rising and the furnace starts off with cool walls and a cool top. If lead makes too slowly and shows a tendency to cool in the well, a few bars can be dipped out and charged into the furnace again.

With this hasty survey we must leave the subject of lead-silver ore smelting. You cannot fail to realize that neither methods or their limits are yet well defined.

The aim of the best metallurgists may be summed up in a few words :

1. The largest furnaces compatible with good work.

2. Slags which will permit the largest amount of refractory and hence profitable ingredients.

3. A perfect initial separation of slag, matte and bullion by automatic appliances, with mechanical handling of the slag.

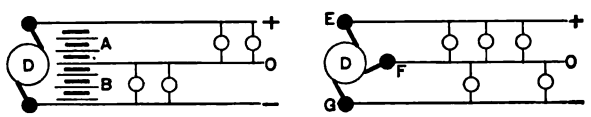
4. Economical treatment of lead copper mattes.

PRINCIPLES OF ELECTRICAL DISTRIBUTION.—III.

By FRANCIS B. CROCKER.

Modifications of the Three-wire System.

Various forms of the three-wire system have been used or suggested as substitutes for the ordinary arrangement with two dynamos. One of these modifications, illustrated in Fig. 25, requires only a single dynamo *D* generating the total pressure for both sides of the system, which is usually about 230 volts. A storage battery *A B* is connected between the two outside wires + and —, the neutral wire o being led to the middle point of the battery. In cases where it is advantageous to employ a battery to equalize the load on the engines, or for other reasons, this plan is a convenient one, since it only necessitates the running of one dynamo. The potential of the neutral wire o may be varied to make up for differences in load on the two sides of the system by shifting the point at which it is connected to the battery. If the



Figs. 25 and 26.—Three-Wire Systems.

difference of potential between the two outside conductors is greater than the E. M. F. of the battery, the latter will be charged, and *vice versa*, the same as in a two-wire system. With a three-wire circuit it is also possible for one part, *A*, of the battery to be discharging while the other part, *B*, is charging. This may occur if there are a great many lamps on the + side, and very few lamps on the — side. The function of the battery is to act as an equalizer, taking or giving current, as required, and keeping the neutral

wire approximately midway in potential with respect to the two outer conductors.

Fig. 26 indicates another three-wire arrangement that can be operated with only one generator *D*, the neutral wire being connected to a third brush *F* placed half way between the main brushes *E* and *G*, to which the outside wires + and — are respectively attached. With most types of dynamo the brush *F* would spark excessively because it short circuits the armature coils when they are generating the maximum E. M. F. There are several ways to avoid this difficulty, one of which consists in employing a four-pole dynamo, Fig. 27, having two adjacent north poles *N* and *N*, the other two being south poles, *S* and *S*. The machine thus becomes in effect a bipolar dynamo with each pole divided, the armature coils short-circuited by the brush *F* being in the space between the two halves *S* and *S* of the south pole, where they generate little or no E. M. F. A dynamo to be used in this way requires a field magnet ring of sufficient cross-section between the *N* and *S* poles (*i. e.*, at the top and bottom in Fig. 27) to carry the total magnetic flux of one field core. In an ordinary multipolar machine with alternate *N* and *S* poles this ring need only have one half the sectional area. Since practically no flux passes through the two sides of the ring they might be greatly reduced in size, but this is limited by considerations of strength and appearance. The radial depth of the armature core must also be sufficient for the total flux of one field core. The extra quantity and less favorable disposition of material in the generator is not a very serious matter however, and this plan of operating a three-wire system would often be a very practical and convenient one for small plants.

There is, however, with this arrangement the difficulty that armature reaction tends to increase the flux in the lower *S* pole and reduce it in the other, hence the voltage on the + side of the system would be less that on — side with heavy loads. This can be counteracted by compound winding on the upper *S* pole and differential winding on the lower *S* pole. Another way to supply a three-wire system with a single dynamo was devised by Dobrowolsky. It consists in connecting two opposite points of a gramme ring armature together through a self-induction coil, to the middle point of which coil the neutral wire of the system is attached. The self-induction of this coil prevents it from acting as a short

circuit, but causes the neutral wire to maintain a potential approximately midway between the + and — wires.*

In the three-wire system represented in Fig. 28 the neutral wire O is connected to an auxiliary machine *H* which supplies a potential one half as great as that of the main dynamo *D*. The machine *H* acts as a generator when the — side requires more current than the + side, but it runs as a motor when the current on the + side is greater. Hence it should be belted to or directly coupled with the dynamo *D* in order to save its power when acting as a motor.

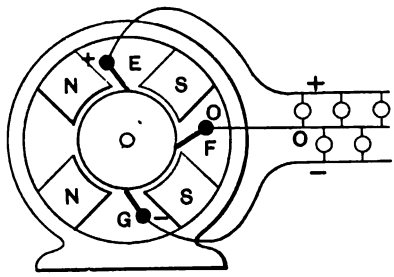


FIG. 27.—THREE-WIRE SYSTEM WITH ONE DYNAMO.

The machine *H*, being intended to carry only the difference between the currents on the two sides of the system, may have only 5 or 10 per cent. of the capacity of the dynamo *D*. This is sufficient as long as the sides are fairly well balanced, but is entirely inadequate if the difference becomes great, which may easily occur by accident. The ordinary three-wire arrangement, or that shown in Fig. 26, has the advantage of being able to operate, if necessary, with a full load on one side and none on the other, which might occur if there was an open circuit on one of the outside wires, due to the blowing of a fuse or to some other cause.

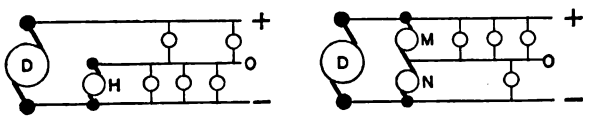
The same reasoning applies to the storage battery in Fig. 25, which may be designed to have a capacity equal to the full load or only a fraction of it.

In Fig. 29 the two auxiliary machines *M* and *N* are mechanically coupled together and each generates one half as much pressure as the main dynamo *D*. These machines serve to equalize the pressure and load, the one on the more lightly loaded side running as a motor and driving the other as dynamo. Hence

*U. S. Patent, No. 513006, Jan. 14, 1894.

they are capable of operating with a difference in energy on the two sides of the circuit, equal to their combined capacity.

This combination involves three machines in place of the two dynamos required in the ordinary three-wire system, nevertheless, it is very commonly and successfully used, being in many cases decidedly preferable to the latter. The two machines *M* and *N* are entirely self-acting, driving each other mechanically and maintaining equal voltages, with very little attention or likelihood of trouble. They are much more easily operated than a second dynamo, and the friction and other losses involved are also considerably less. If both armature windings are upon the same core, armature reaction is neutralized and the tendency to sparkling greatly reduced. A still more important advantage is the fact that the double machine *M N* can be placed at any desired distance



FIGS. 28 AND 29.—THREE-WIRE SYSTEM.

from the generating plant and connected to it by two feeders, three wires being required only for the local distribution. It is also possible to run a "booster" or small auxiliary series-dynamo by means of the equalizing machines *M* and *N*, in order to raise the pressure of the circuit and make up for drop on the conductors. This and several other applications of equalizing machines are described in *The Electrical World*, May 23, 1896, p. 596.

The storage battery represented in Fig. 25 can also be placed at a distance from the generator in order to secure a similar saving in the number of conductors. It possesses the additional advantage over the equalizing machines that it enables the current on the feeders to be made more uniform, the battery being charged during periods of light load and discharged when the demands for current are great. This permits feeders of smaller size to be used, and also reduces the variations in load on the generating plant, so that the latter operates more efficiently and can be designed for less capacity than the maximum load.

Conversion from Three to Two-Wire System. A three-wire system of conductors can readily be connected so that it may be used

as an ordinay two-wire circuit. For this purpose the two outside wires are connected to one terminal and the middle wire to the other terminal of the generator, as represented in Fig. 30. The lamps are fed between the middle conductor and either of the others, but the direction of current is reversed in all of those that are on one side of the system. This makes no difference in the operation of incandescent lamps, but would require the connections of arc lamps to be reversed, the same being true of storage batteries, electroplating cells or other electrochemical apparatus that may be on that side of the system. Motors operated on one side of the circuit would not be affected since the direction of rotation is not changed by reversing the current in both armature and field coils. But a motor or other device connected across the

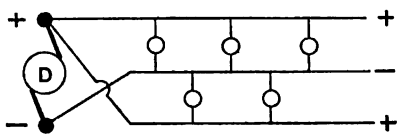


FIG. 30.—CONVERSION FROM THREE-WIRE TO TWO-WIRE SYSTEM.

outside wires, which is the usual arrangement for the former, would receive no current because these wires are of practically the same potential when used as a two-wire circuit.

The drop on the conductors is greatly increased by conversion to the two-wire arrangement. In a perfectly balanced three-wire system there is practically no current or drop on the middle wire, but when used as a two-wire circuit the current and drop on this conductor is twice that in either of the others, consequently the total drop is three times as great as before. There is also danger of blowing the fuses on the middle wire, or overheating it, unless it is specially designed to be used in this way.

There are two cases in which the conversion from the three to the two-wire system is commonly practiced. First, a central station or isolated plant, which is operated on the three-wire plan, when heavily loaded, and on the two-wire plan for light loads, one dynamo being sufficient in the latter case, and the drop on the conductor being quite small. Second, an isolated plant, which is supplied by its own generator most of the time, but is connected to the three-wire "street circuit" (*i. e.*, central station conductors) during certain portions of the day or night, or in case its machin-

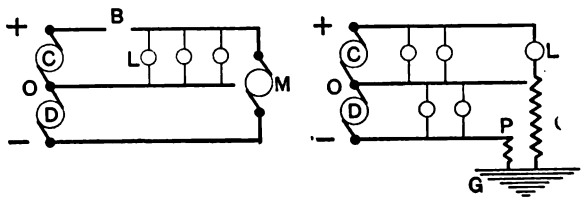
ery is disabled. On account of the latter contingency the name "breakdown switch" is applied to the device, which connects the inside wiring to the outside conductors. This switch is so made that it simultaneously opens the connections with the local generator.

Laying and Operating Three-wire Systems.

The general arrangement of three-wire feeders and mains may be made substantially the same as already described for the two-wire system, the same methods and care being used in regulating the voltage. The feeders may consist of three conductors of the same size, but usually the neutral feeder is made one-half as large as either of the others, and if storage batteries or equalizing machines are placed at the outer ends of the feeders, the neutral conductor may be omitted, as previously explained on page 369. For the mains and leads the three wires are generally made the same in size. The important point in connection with the three-wire system is the necessity for carefully *balancing* it; that is, keeping the currents on the two sides approximately equal. To accomplish this, the lamps and other devices requiring current are divided between the two sides of the system so that the loads shall be as nearly as possible the same for full capacity or any fraction of it. For this reason all three wires should be carried to any point where energy is required unless the amount is extremely small. This applies to every building even though it contains only a few lamps, and in fact, to almost every room that is to be supplied with current. In this way the chance of having any considerable difference in load is reduced to a minimum.

Nevertheless, it is possible that a great many lamps might happen to be lighted on one side of the system and very few on the other side, in which case the drop in voltage would have about twice its normal value for the larger number of lamps, while the pressure might be raised for the smaller number, as already explained (Fig. 22). The likelihood of this happening is small, however, particularly in large systems, provided the lamps are carefully divided in wiring them. In case many lamps are to be lighted at the same time, they should be controlled by the three-pole switches, which connect them to the two sides equally, or they should be divided into groups which are thrown on the sides alternately.

Grounding the Neutral Conductor. A question that has aroused much discussion is the advisability of purposely grounding the neutral conductor of a three-wire system. The two principal



FIGS. 30A AND 31.—PECULIAR CONDITIONS ON THREE-WIRE SYSTEM.

arguments in favor of this plan are: First, it practically limits the potential between any point on the system and the earth to about 110 volts. Second, it greatly reduces the drop on the neutral conductor, since the current can also flow through the earth. In regard to the first of these reasons, it is a fact that the potential of the positive wire may rise to 220 volts if the negative wire becomes grounded, or *vice versa*, when the neutral wire is insulated. But it can hardly be said that trouble would be avoided if the neutral were grounded, as the effect of a ground on either of the other sides would then be to make a short circuit which would blow the fuse of that wire, and perhaps that of the neutral also, thus putting out the lamps on that portion of the circuit. To be sure this locates the trouble and calls for immediate attention, which may be a simple, but is also a crude way to keep the circuits clear of faults. If an accidental ground connection exists on one of the conductors when the neutral wire is not grounded, no trouble results until another ground occurs on one of the other two conductors. In the meantime an opportunity is afforded to correct the fault before any interruption of service or difficulty of any kind is experienced.

Unfortunately it is very troublesome to detect and locate a ground connection even on a two-wire circuit and still more so with three wires. Nevertheless there are methods which will accomplish this result, and if these were more generally used they would be found to afford reasonably practical and convenient means of taking care of three-wire systems. But these methods fail; in fact the problem is practically impossible to solve if the neutral wire is grounded.

Regarding the second advantage of grounding the neutral conductor, it may be said that it is well enough to use the earth to re-

inforce the conductance of the circuit, provided no serious difficulty results. But it is found that great damage is done by electrolytic action on gas, water and other kinds of pipes if large currents are allowed to flow promiscuously through the earth. In the case of electric railways with overhead trolleys it is necessary to allow the current to pass into the track or else adopt the double-trolley system, which is complicated and not considered practicable. But even for the trolley system the tendency is to demand more perfect bonding of the rails, and the use of return feeders to reduce the stray currents. In electric lighting no very strong reason exists for intentionally grounding the circuit or any portion of it, except perhaps the secondary circuit of a transformer, as a safeguard in case the high-tension primary circuit accidentally connects with the secondary.

Insurance and fire department authorities are vigorously opposed to grounding the neutral of a three-wire system, or, in fact, any part of an electrical circuit, their experience having convinced them that it is the source of much danger and trouble. It is because of this opposition that the practice has been abandoned or avoided as far as possible, as many central station officers would prefer to ground the neutral conductors.

Peculiar Conditions on a Three-wire System. The following cases may occur:

1. The dynamo or dynamos on one side of the system may be accidentally reversed, so that both of the outside wires are positive or both negative. In that case a motor or other device fed by the two outside conductors will receive no current, but lamps, etc., connected between the neutral and either of the outside wires will have the usual voltage reversed, however on one side.

2. If one of the outside wires is open at B, Fig. 30a, due to the blowing of a fuse or other cause, a motor, M (220-volt), beyond the break, B, will receive some current at 110 volts through any lamps, L, that may be on the same side of the break as the motor, and on the same side of the system as the break. These lamps will light up when the motor is connected, but the latter will not have much power.

3. If the neutral wire is open, a motor or other device connected to the outside wires will act as usual, but lamps on one side of the system will burn more brightly than those on the other side, unless the two sides are exactly balanced.

4. If one of the outside wires, Fig. 31, becomes grounded at *P*, a 110-volt lamp, *L*, or other apparatus, also grounded and connected to the other outside wire, will receive 220 volts which is likely to deistroy it.

Five-wire Systems.

The principle of the three-wire system may be extended, in order to effect a still greater saving of copper in electrical distribution. It would be possible, for example, to have a four-wire system requiring two-ninths as much copper as an equivalent two-wire circuit, but, for reasons to be given later, it has rarely, if ever, been tried. The five-wire system is employed in many places in Europe, but has not been introduced to any extent in this country. It may

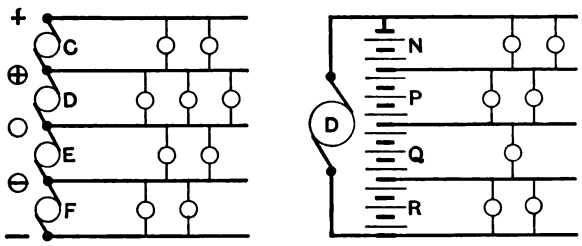


Fig. 32 and 33.—Five-Wire Systems.

be operated with four dynamos, *C*, *D*, *E* and *F*, as represented in Fig. 32, but the arrangements shown in Figs. 33 and 34 are more common. The second of these is similar to the three-wire system illustrated in Fig. 29, only one main dynamo, *D*, being required, and the total pressure generated by it, ordinarily about 440 volts, is subdivided by the four small equalizing machines or compensators, *J*, *K*, *L* and *M*. These may consist of four separate machines mechanically connected together, or they may be made with all of their armature windings upon the same core and acted upon by one field magnet, in order to neutralize the effects of armature reaction. Fig. 33 shows a combination similar to the three-wire system represented in Fig. 25, a battery, *N*, *F*, *Q*, *R*, being utilized to subdivide the voltage of the main dynamo *D*. The conductors are designated as shown in Fig. 32, the two extra wires being called the "positive neutral" ⊕ and the "negative neutral" ⊖ respectively.

The comparative weight of copper required for the five-wire

system may be determined by reasoning similar to that used in connection with the three-wire diagrams (Figs. 23 and 24). But it can be arrived at more simply by considering that the current in each of the outside wires of a perfectly balanced five-wire system is one-quarter as much as in a two-wire circuit supplying the same number of lamps. Hence the drop is only one-quarter as great in the former case, assuming the conductors to be of the same size. But since with five wires, there are four sets of lamps in series, the *percentage* of drop is $\frac{1}{4} \times \frac{1}{4} = \frac{1}{16}$ as much, or in other words, each conductor need be only one-sixteenth as large for the same percentage of drop. Therefore the two outside conductors of the five-wire system weigh one-sixteenth as much as those of an equivalent two-wire circuit and the five conductors weigh $\frac{5}{2} \times \frac{1}{16} = \frac{5}{32}$ as much if all are made of the same size. By making each of the three intermediate wires one-half as large as each of the outside ones, the total weight is reduced to $\frac{1}{16} + \frac{3}{2} \times \frac{1}{32} = \frac{7}{64}$, or less than one-eighth as much copper as the two-wire circuit demands. The various results that have been obtained may be recapitulated as follows:

Comparative weights of copper required.

Ordinary two-wire system	1.000
Three-wire system, all three wires of same size	.375
Three-wire system, neutral one half size	.313
Four-wire system, all four wires of same size.	.222
Five-wire system, all five wires of same size	.156
Five-wire system, three inside wires one-half size	.109

It is evident that similar systems having a greater number of wires might be designed, but they would be extremely complicated and of very doubtful advantage. In fact, the desirability of a five-wire system is questionable, since the use of 220-volt lamps enables three-wire circuits to be operated at 440 volts. A five-wire system calls for an even more perfect balance of load than is needed for three-wire circuits. This is secured by carefully dividing the lamps, etc., between the four parts of the system so that the loads may be as nearly equal as possible at all times. To this end all five wires should be carried wherever any considerable amount of energy is likely to be used, as represented at *A* in Fig. 34. If the demand for current is small it is only necessary to run three wires, as shown at *B*. But in this case an approximately equal load *P* should be connected to the other side of the system.

For very small loads, *E*, *F*, *R* and *S*, it may be allowable to put them on the separate parts of the systems, provided they are equally distributed as represented. Motors should generally be supplied from the two outside wires (440 volts) as indicated at *N*,

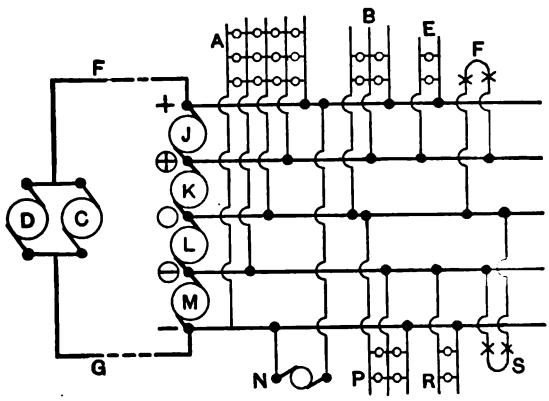


FIG. 34.—FIVE-WIRE SYSTEM.

but if they are not large they may be connected to the + and o or to the o and — conductors (220 volts) at *B* or *P*, and very small machines, such as fan motors, may be connected to adjacent wires (110 volts) at *E* or *R*. Arc lamps may be arranged as shown at *F* and *S*, or a suitable number may be put in series across the outside wires at *A* or *B*.

The flow of the currents and values of the potential in five-wire systems may be determined by extending the methods already described in connection with three-wire circuits. Although apparently a complicated matter, a problem of this kind can be solved without much difficulty in most cases. In practice, the current to be supplied is usually known, or its probable value may be assumed. A diagram similar to Fig. 35 should then be made, showing the arrangement of circuits and distribution of current. It is much simpler and in most cases sufficiently accurate to consider the lamps or other apparatus requiring energy, to be located in groups, approximating as closely as possible their actual positions.

This enables the conductors to be divided into sections, in each of which the current is uniform, as represented in Fig. 35. The determination of the amount and direction of the currents in the various sections is easily made. If 10 amperes are required at *E*

and also at *F*, it follows that that amount of current will flow out on the + wire and half-way back on the ⊕ wire, there being no current in the rest of this conductor. Since 5 amperes are required at *G*, one-half of the 10 amperes will flow out to that point and the other five amperes will return to the dynamo through the O conductor, the function of the three neutral or intermediate wires being to carry the *difference* between the currents used in the adjacent portions of the system, whatever its amount and direction may be.

The five amperes required at *H* are supplied by the ⊖ conductor, and the 5 amperes used at *J* by the same current that flows through *G*, hence there is no current in the outer half of the ⊖ wire. The currents from *H* and *J* return to the dynamo *D* by the

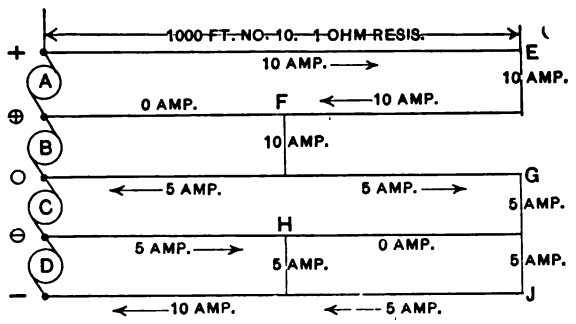


FIG. 35.—DISTRIBUTION OF CURRENT IN FIVE-WIRE SYSTEM.

— conductor as shown. In a similar manner the flow of current in any multiple-wire system may be determined, no matter how large or how small the loads on the different parts may be.

The next step is to determine the voltage at the various points, as indicated in Figs. 36 and 37. Let us first consider the case (Fig. 36) of 10 amperes being required at *E*, with no current used in the rest of the system. Assuming each conductor to have one ohm resistance, the drop on the + is 10 volts and the same on the ⊕ wire, so that the lamps receive only 95 volts, the pressure at the dynamo being 115 volts. There will be no drop on any of the other three wires, since no current is drawn from them. It is interesting to observe that the potential difference between the extremities of the ⊕ and O wires will be 125 volts, as shown in Fig. 36. If three other groups of lamps were added so that 10 amperes

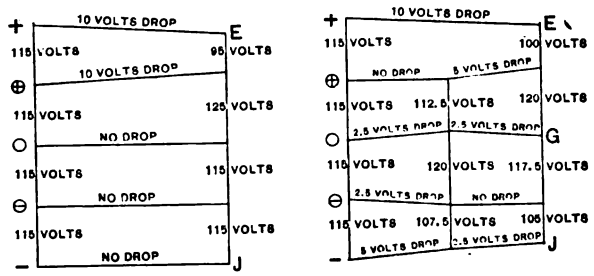
would flow directly across from *E* to *J*, the total drop would be 20 volts as before, 10 volts drop being transferred from the ⊕ to the — wire, and each group would receive 110 volts instead of 95, the aggregate number of lamps being four times as great. This brings out forcibly the advantage of a perfectly balanced five-wire system over a two-wire circuit, which the first case practically amounted to.

With groups of lamps placed at *E*, *F*, *G*, *H* and *J* (Fig. 37), the pressure is far from uniform, although the system is fairly well balanced in the number of lamps, but not in their position. This potential diagram is made by drawing from the five points marked +, ⊕, O, ⊖ and — lines representing the pressure in the respective conductors and portions thereof. By comparing Figs. 35 and 37 it will be seen that the direction of these lines is easily and definitely determined, the drop or slope of each section being equal to its resistance multiplied by the current flowing in it. In this connection it should be noted that the current in each group of lamps has been assumed to be constant, but it is evident that the group at *J*, receiving only 105 volts, will take less current than those at *G*, where the pressure is 117.5 volts. This fact might be allowed for by modifying the values of the current in proportion to the voltage, but the resistance of the lamps also varies, so that it would be very difficult to calculate the current that each group would take. In practice conductors are designed to supply a given current at a certain point, and slight variations in current due to changes in resistance, working conditions, etc., are not usually considered.

This may appear to be a somewhat rough method, but is not only justifiable, but practically unavoidable. In electric railway work for example, the current required by a car varies greatly with the speed, grade, condition of track, load on the car, etc. Hence the only practicable plan is to assume a certain average current, or a certain maximum current in designing the generating plant, conductors, etc. The average current corresponds to the ordinary working conditions and the maximum current to the greatest possible requirements. The same is true for electric lighting in which variations in the resistance of lamps are far less important than the changes in the number of lamps which are continually being made.

In practice the electric light engineer considers the *initial voltage* at the generators, the *drop on the conductors*, which gives him the

voltage at the lamps and the *current to be supplied* to them. He could easily calculate the resistance of the lamps by dividing the voltage by the current flowing through them, but as a matter of fact he rarely, if ever, does this. It is only the inexperienced student who attempts to apply Ohm's law to the circuit as a whole. The practicing engineer confines it to determining the drop on the



FIGS. 36 AND 37.—DISTRIBUTION IN POTENTIAL OF 5-WIRE SYSTEMS.

wires, which is equal to their resistance multiplied by the current carried by them. The same is true in power transmission and distribution, including electric railway work. In fact it is practically impossible to predetermine the resistance of the whole circuit except in very simple cases. The writer has never before seen this fact pointed out, although it distinguishes the professional from the amateur without fail.

Seven-Wire Systems. This is the next higher multiple-wire system that would be used, since it can readily be divided into two four-wire systems, or three three-wire systems, in order to supply current to individual buildings where it is not necessary to carry all seven conductors. Neither the four-wire nor the six-wire systems are capable of being conveniently divided into equal parts in this way, hence they are not to be recommended for adoption, except perhaps in some special case. The seven-wire system, with all conductors of the same size, requires 0.0972, or a little less than one-tenth as much copper as an equivalent two-wire circuit, but its complication is so great as to make it of very questionable desirability. Its design and operation would be similar to that of the three- and five-wire systems already described.

DIRECT CURRENT CONVERTERS.

The fact that electrical energy can be readily transformed from

a higher to a lower voltage, or *vice versa*, constitutes one of its most important advantages, and enables it to be conveniently and economically transmitted and distributed. The most prominent example of this method is the ordinary alternating current system, in which a high pressure of a thousand volts, or more, generated by the dynamos, may be carried by small wires to a considerable distance, and there transformed to a low voltage that is harmless to persons and adapted to supply lamps, etc.

The direct current can also be transmitted in a similar manner, but it requires rotary converters instead of the simple static transformers which are used for the alternating current.

Rotary converters consist of a motor and a dynamo combined, the former being driven by the current from the main or *primary circuit*, and the latter generating the current for the *secondary circuit*, by which the lamps, etc., are supplied. It is obvious that the dynamo may be designed to produce any desired voltage without regard to that of the primary circuit. But in every case the watts—product of the volts and amperes—are less in the secondary circuit by an amount corresponding to the frictional and other losses which necessarily occur. This device has been given many names, such as dynamotor, motor-dynamo, motor-transformer, rotary-transformer, motor-converter and rotary converter. The first of these has the advantage of being a single word, but has been objected to because the order in which the two machines work is inverted, hence the second name is more often used, although less euphonious. The word transformer has been almost universally adopted for the induction coil or static transformer, so that the term converter, which was formerly applied to this device, is now free to be used for the rotary or motor-converter. There is certainly no advantage in having two names used indiscriminately for two different things; whereas it would be convenient and avoid confusion if they were employed respectively in the manner here suggested.

In many instances the two armature windings are placed on the same core and are acted upon by the same field magnet. This construction secures compactness and also causes the armature reaction of the dynamo to practically neutralize that of the motor, thereby avoiding sparking and other troubles. But it is open to the objection that it is somewhat difficult to insulate the two windings from each other, and absolutely prevent the high voltage of

one from breaking through to the other. Therefore, this arrangement is not desirable where there are great differences in potential between the primary and secondary circuits, unless special precautions are taken. Another limitation of this construction is the difficulty of acting on the two armature windings independently for purposes of regulation. Since both are wound upon the same core and are under the influence of the same field, it is hardly possible to change the speed, magnetic flux or other conditions of one with respect to the other. In other words, the ratio of conversion, that is, the relation between the primary and secondary voltages, is practically constant, no matter how much the speed or flux may be varied. To be sure, the difference of potential between the secondary brushes may be decreased by introducing resistance in the primary circuit, but this merely has the effect of reducing the available voltage supplied to the motor. The amount of this reduction is the drop $= IR$, in which I is the primary current and R the resistance. A corresponding decrease in voltage is produced in the secondary circuit, but the ratio of conversion remains substantially unchanged. Resistance put in the secondary circuit will have a similar effect in decreasing the available potential, but in either case the loss of energy is considerable, its value in watts being I^2R. The so-called "regulation" is also seriously interfered with; that is, the available secondary voltage varies greatly with changes in the load, because any alteration in the current has a corresponding effect on the drop IR. Such a variation in pressure would usually be very objectionable; in electric lighting, for example, the voltage would fall as more lamps were added in parallel.

In order to secure independence of action between the motor and the dynamo portions of a rotary converter, the two armature windings should be carried by separate cores, each being acted upon by its own field magnet. This allows the field of the dynamo to be independently regulated, in order to vary the voltage generated. In fact, any of the well-known methods of dynamo regulation may be employed. For example, compound or over-compound winding will give a constant or a rising pressure, with increase of current in the secondary circuit. In these cases, the separate armatures may be mounted upon the same shaft, with only one pair of bearings, in order to combine the two parts in one machine, or two entirely distinct machines may be connected directly or by belting.

It is evident that the motor of a rotary converter may be designed to operate with an alternating current, and the dynamo to generate a direct current, or *vice versa*, in order to convert alternating to direct currents, or the converse.

Another type of a rotary converter is that in which the same armature winding performs both the motor and dynamo functions. A simple form of this machine, shown in Fig. 38, consists of a ring

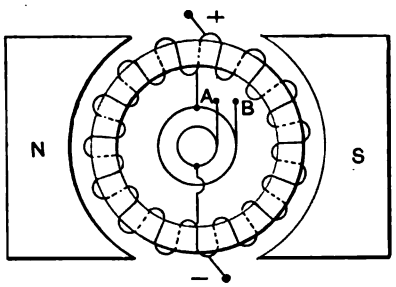


FIG. 38.—DIRECT-ALTERNATING CURRENT CONVERTER.

armature, diametrically opposite points of the winding being respectively connected to two collecting rings. When the armature is supplied with direct current in the usual way by the brushes + and —, it will revolve as a motor, and an alternating current may be obtained from the brushes *A* and *B*. This action can be easily understood when it is considered that the outer collecting ring is connected to the top or + point of the winding and the inner ring to the bottom or — point of the winding, hence the current tends to flow from the brush *B* to the brush *A;* but when the armature has turned through 180 degrees, or half a revolution, these conditions will be exactly reversed, and the current tends to flow from *A* to *B*. Thus it is seen that an armature having only a single winding may be fed with a direct current, and will give out an alternating current. The ratio between the primary and secondary voltages is practically fixed in this form of converter, since the maximum value of the alternating E. M. F. is equal to the voltage of the direct current, as is evident from the diagram. With a true sine wave the effective value of the alternating E. M. F. is 0.707 of the direct E. M. F.

The current capacity of one of these machines when used as a converter is usually greater than its ordinary capacity as a generator since the current flows directly from the primary to the second-

ary circuit for a portion of the time without passing through the armature coils.

If these machines are used to convert alternating to direct current, they are run as synchronous motors; hence they must first be brought up in speed by some extraneous power until they are in synchronism with the alternating current by which they are to be operated. These machines are capable of exciting their own field magnets.

By tapping the direct current winding at three points or four points, machines are made for generating or utilizing two or three phase alternating currents.

Rotary Converter Systems of Distribution. The usual arrangement of rotary converters in electrical distribution is that represented in Fig. 39, being analogous to the ordinary alternating current sys-

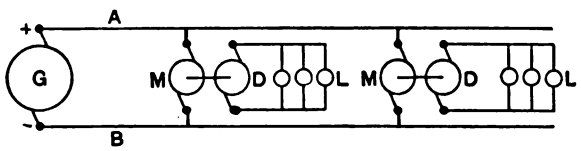


FIG. 39.—DISTRIBUTION BY ROTARY CONVERTERS IN PARALLEL.

tem with static transformers. The current produced by the main generator *G* is carried to the converters by the conductors, *A* and *B*, to which the motor portions *M* of the rotary converters are connected in parallel. These motors are provided with shunt wound field coils, consequently they run at a practically constant speed. The dynamo portion *D* of the converters are connected to the secondary circuits which supply the lamps, etc., *L*, as indicated. The field magnets of these dynamos may also be fed by the main circuit *AB*, or they may be self-excited by shunt or compound winding. This system has several disadvantages compared with the alternating current system. Rotary converters are more complicated, cost more, require more attention and are less efficient than static transformers. But it has been shown that they may be compound or over-compound wound, in order to supply a uniform voltage, which is not practicable with static transformers. Furthermore, it is generally found that rotary converters are easily taken care of and rarely get out of order. In many cases their use may be desirable or necessary, as, for example, in electrochemical or electrometallurgical work, in connection with storage batteries, or

for many purposes where it is required to convert direct currents to a higher or lower pressure.

Rotary converters may also be arranged as illustrated in Fig. 40, the motor parts of *M* being all connected in series with the main generator *G*, and the dynamo parts *D* of the converters being connected to the lamps, etc., *L*. If the current is kept constant (the generator *G* having a regulator like an arc lighting dynamo), and the motors *M* are simple series wound machines, they will exert a

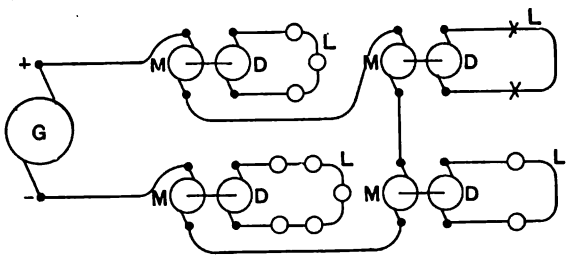


FIG. 40.—DISTRIBUTION BY ROTARY CONVERTERS IN SERVICE.

certain torque or turning effort which will be constant. It follows, therefore, if the dynamos *D* are also series wound, that each will generate a certain current which will be constant. If lamps or other devices designed for that particular current are connected in series on the secondary circuits, the dynamos *D* will always maintain that current, no matter how many lamps there may be. When lamps are added the resistance of the local circuit is raised and the current in it decreases, so that the dynamo increases its speed until it generates sufficient E. M. F. to produce practically the same current as before. Hence this constitutes a system which is self-regulating, when lamps, etc., are cut in or out of the secondary circuits. No harm results even when the secondary is short-circuited, since only the normal current can be generated. But if the secondary circuit is opened, then the machine will race and probably injure itself by centrifugal force, because the torque of the motor *M* has its full value, and there is no load upon the dynamo *D*. To guard against this danger, some automatic device should be provided to short-circuit the field or armature of the motor when its speed or counter E. M. F. rises above a certain point. Another way to operate such a system would be to use motors *M* with governors which maintain a constant speed for all

loads, in which case the dynamos *D* should be shunt or compound wound, to feed lamps, etc., in parallel at constant potential.

This practically completes the important principles and methods that are employed in the distribution of direct currents. Those used for alternating currents are quite similar, the principal differences being due to the fact that self-induction and capacity must be considered in addition to simple ohmic resistance.

AN INTRODUCTION TO THE STUDY AND EXPERIMENTAL DETERMINATION OF THE CHARACTERS OF CRYSTALS.

By ALFRED J. MOSES, Ph.D.

(Continued from page 288.)

CHAPTER IV.

THE THIRTY-TWO CLASSES OF CRYSTALS.

In this classification, following Professor Groth, the conception of hemihedral and tetartohedral forms is abandoned because the geometrically connected whole and partial forms *have no structural connection and are incapable of occurrence upon crystals of the same substance.*

Each occurring form is, therefore, considered to be complete and independent, and with a grade of symmetry which is not in every case determinable from a consideration of the grouping of the faces, but involves the far wider conception that two directions are not structurally equivalent *unless they are equivalent with respect to all properties*, and that two forms geometrically identical are not structurally so if in corresponding directions there is revealed an essential difference in behavior with polarized light or etching or pyroelectricity or any other test, the results of which depend upon the manner the crystal molecules are built together.

With this conception the same geometric form may occur on crystals structurally different, and is to be regarded as in each case a limit form of geometrically distinct general forms. If a class be made of each conceivable variation of general form and its geometric limit forms, two great essentials will be fulfilled:

1. All known and some unknown forms will be classed.

2. Each class will consist of forms capable of occurring upon crystals of the same substance, and will contain all the forms which can occur on these crystals.

There have been distinguished thirty-two grades or classes of symmetry which may be united into six systems by grouping together classes in which the selected axes of reference are geometrically similar.

In the stereographic projection of the general form given under each class all full lines, whether diameters, circles or arcs of circles represent planes of symmetry and the small black ellipses, triangles, squares and hexagons represent the axes of binary, ternary quaternary and senary symmetry.

TRICLINIC SYSTEM.

This system must include all crystallographic forms which can only be referred to three non-equivalent axes, Fig. 39, at oblique angles, α, β, and γ, to each other.

The selection of axes is arbitrary, two edges are chosen as directions of the basal axes, *a* and *b*. Two planes from the zones of these edges are chosen as {100} and {010} and their intersections are the vertical axes *c*.

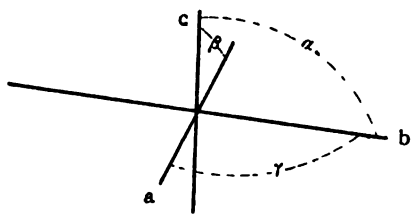


FIG. 39.

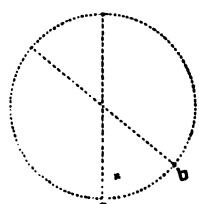


FIG. 40.

1. UNSYMMETRICAL CLASS.

Without either planes or axes of symmetry. The projection, Fig. 40, shows that the symmetry of the class is satisfied with one face for the most general form. EXAMPLE.—Calcium thiosulphate, $CaS_2O_3.6H_2O$.

2. CLASS OF PINACOIDS.

With composite symmetry to a binary axis and a plane normal thereto.

As shown in projection, Fig. 41, any upper face indicated by × would by simultaneous rotation around the axis and reflection in the plane coincide with the diametrically opposite lower face, that is, the symmetry of the class is satisfied by two faces for the most general form or PINACOID (Tetarto Pyramid), Fig. 42. EXAMPLES.—Albite, cyanite and chalcanthite.

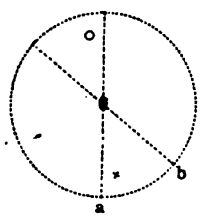


FIG. 41.

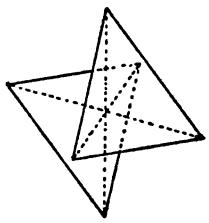


FIG. 42.

THE SIX LIMIT FORMS.

In each class there are six limit forms corresponding to six special positions of the faces of the general form. In Class 2 these will be pairs of parallel planes, and in Class 1 single planes only.

Position of any Face.	*Symbol.*	*Class 1.*	*Class 2.*
1. Parallel to *a* and *b*.	{001}	PLANE of Fig. 43.	PINACOID Fig. 43.
2. Parallel to *a* and *c*.	{010}	PLANE of Fig. 44.	PINACOID Fig. 44.
3. Parallel to *b* and *c*.	{100}	PLANE of Fig. 45.	PINACOID Fig. 45.
4. Parallel to *a*.	{0*kl*}	PLANE of Fig. 46.	PINACOID Fig. 46.
5. Parallel to *b*.	{*h*0*l*}	PLANE of Fig. 47.	PINACOID Fig. 47.
6. Parallel to *c*.	{*hk*0}	PLANE of Fig. 48.	PINACOID Fig. 48.

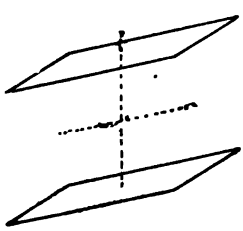


FIG. 43.

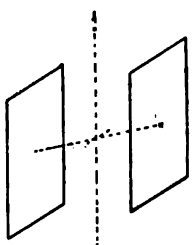


FIG. 44.

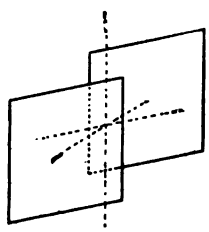


FIG. 45.

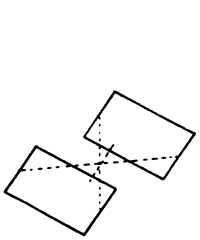


FIG. 46.

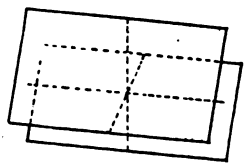


FIG. 47.

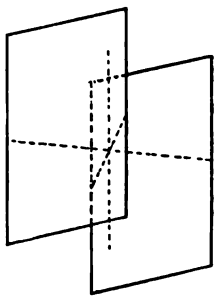


FIG. 48.

PROJECTION AND CALCULATION OF TRICLINIC FORMS.

THE PROJECTION is conveniently made upon a plane normal to the vertical axis c. All planes in the zone of c as (100), (010); (110), being projected in the primitive circle at the measured angles apart.

The pole of any face P will lie at the intersection of two circles found as follows:* Their centers are on prolongations of diameters through A(100) and B(010) and distant from the center O of the primitive circle respectively $OK = \frac{r}{PA}$, $OL = \frac{r}{PB}$; and their radii are respectively $Kp = r \tan PA$, $Lp = r \tan PB$.

Most of the poles are found by zones and problem 3, p. 286.

THE CALCULATIONS are principally solutions of spherical triangles † and of equations which connect measured angles with

*Groth, *Physikalische Krystallographie*, p. 580, III. ed.

† *For right-angled spherical triangles*

$C = 90°$ a, b, c = sides opposite angles A, B, C.

$$\sin A = \frac{\sin a}{\sin c} = \frac{\cos B}{\cos b}, \qquad \cos A = \frac{\tan b}{\tan c} = \cos a \sin B,$$

$$\tan A = \frac{\tan a}{\tan b}, \qquad \cos c = \cos a \cos b = \cot A \cot B$$

In oblique angled spherical triangles

A, B, C denote angles, a, b, c, opposite sides, $\frac{A+B+C}{2} = S$, and $\frac{a+b+c}{2} = s$

$$\frac{\sin A}{\sin a} = \frac{\sin B}{\sin b} = \frac{\sin C}{\sin c}$$

$$\cos A = -\cos B \cos C + \sin B \sin C \cos a$$
$$\cos a = \cos b \cos c + \sin b \sin c \cos A$$

$$\sin \frac{A}{2} = \sqrt{\frac{\sin (s-b) \sin (s-c)}{\sin b \sin c}} \qquad \sin \frac{a}{2} = \sqrt{\frac{-\cos S \cos (S-A)}{\sin B \sin C}},$$

$$\cos \frac{A}{2} = \sqrt{\frac{\sin s \sin (s-a)}{\sin b \sin c}} \qquad \cos \frac{a}{2} = \sqrt{\frac{\cos (S-B) \cos (S-C)}{\sin B \sin C}}$$

indices and elements. Wherever possible the zonal equations, pp. 280–283, are used to simplify the calculations.

DETERMINATION OF ELEMENTS.

The general determination of pp. 277–279 requiring the measurement of five angles between four planes, no three of which lie in the same zone, is followed as in the example there given.

GENERAL EQUATION BETWEEN AXES AND INDICES.

Let any plane the indices of which are *hkl* meet the axes in *HKL*, let the axes meet the surface of a sphere described around *O*, in *XYZ* and let the normal *Op* to *HKL* meet the sphere in *P*. Fig. 49.

From a section through *OHp* it is evident that $Op = OH \cos PX$, and, similarly, $Op = OK \cos PY$ and $Op = OL \cos PZ$. Equating, $OH \cos PX = OK \cos PY = OL \cos PZ$.

From page 277, we have

$$OH = \frac{a}{h}, \quad OK = \frac{b}{k}, \quad OL = \frac{c}{l}$$

Substituting,

$$\frac{a}{h}\cos PX = \frac{b}{k}\cos PY = \frac{c}{l}\cos PZ$$

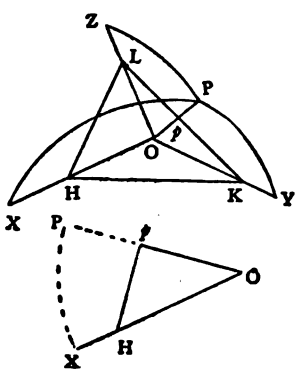


FIG. 49.

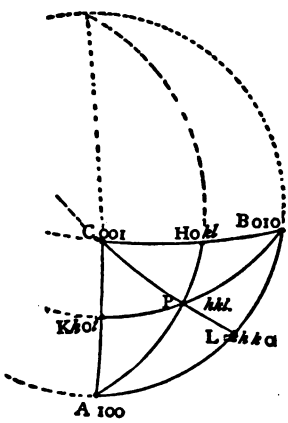


FIG. 50.

TO DETERMINE POSITION OF ANY POLE *P*.

Let Fig. 50 show the poles in projection. From the following equations the position of *P* will result if the indices and elements

are known, or, conversely, the indices will result* if the position is known in one zonal circle.

$$\frac{\sin AB \sin CH}{\sin CA \sin BH} = \frac{\sin CAP}{\sin BAP} = \frac{ck}{bl}$$

$$\frac{\sin BC \sin AK}{\sin AB \sin CK} = \frac{\sin ABP}{\sin CBP} = \frac{al}{ch}$$

$$\frac{\sin CA \sin BL}{\sin BC \sin AL} = \frac{\sin BCP}{\sin ACP} = \frac{bh}{ak}$$

If any five of the arcs in the following are known, the sixth results

$$\sin BH \sin CK \sin AL = \sin CH \sin AK \sin BL.$$

IF THE ELEMENTS ARE UNKNOWN the indices of a face lying in a known zone may be determined by measuring the angle to one face in that zone, and as three faces must already be known, substituting in the formula to find fourth face in a zone, p. 281. Conversely, if the indices of such a plane are known, its position may be calculated.

TO FIND† THE ARC JOINING ANY TWO POLES P AND P'.

Calculate by preceding equations the distances of P and P' from one of the poles A, B or C, and the angles that these distances make with one of the adjacent sides of ABC, therefore, the angle that they make with each other. From two sides and included angle calculate the third side PP'.

MONOCLINIC SYSTEM.

All forms in this system must be referable to three non-equivalent axes, Fig. 51, two oblique to each other, the third, normal to their plane.

Conventionally the normal or ortho axis b from right to left, either of the other axes is made the vertical, c, and the third the clino, a, dips downward from back to front. The acute angle between the vertical and clino axes is β.

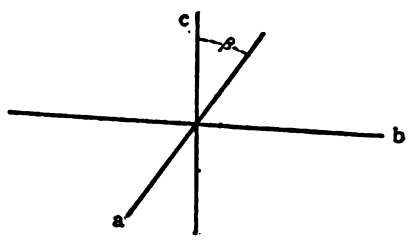


FIG. 51.

* Story-Maskelyne's *Crystallography*, p. 430.

† Miller's *Crystallography*, p. 98.

The system comprises three classes, in which are possible many series each including all the forms which can be referred to the same value for β and to the same parameters a, b, c.

3. Class of the Monoclinic Sphenoid.

With one axis of binary symmetry. As shown in the projection upon (010) Fig. 52, the pole of any face by rotation 180° around the binary axis must reach the pole of an equivalent face. The two faces satisfy the symmetry for the most general form or Sphenoid, Fig. 53. Examples.—Tartaric acid, milk sugar.

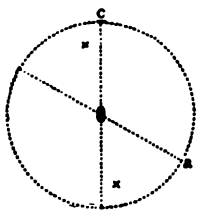


Fig. 52.

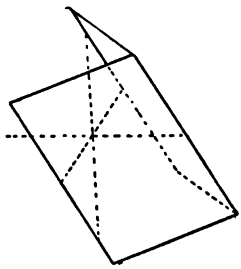


Fig. 53.

4. Class of the Monoclinic Dome.

With one plane of symmetry. As shown in the projection of the general form, Fig. 54 any face reflected in the plane of symmetry coincides with an equivalent opposite face. The two faces satisfy the symmetry of the class for the most general form or Dome, Fig. 55. Example.—Potassic tetrathionate $K_2S_4O_6$.

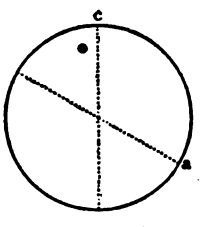


Fig. 54.

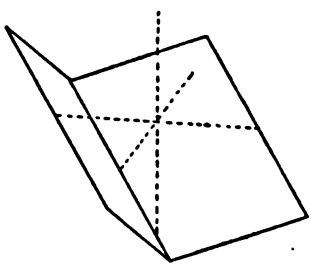


Fig. 55.

5. Prismatic Class.

With one plane of symmetry, Fig. 56, at right angles to an axis of binary symmetry. As shown in projection, Fig. 57, any face

the pole of which is marked × by rotation of 180° around the binary axis coincides with an equivalent face in the alternate octant, these reflected in the plane of symmetry coincide with faces the poles which are marked by a circle.

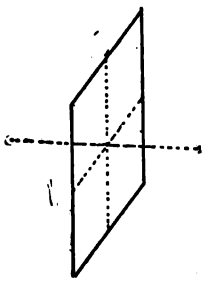


FIG. 56.

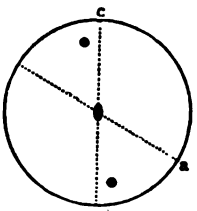


FIG. 57.

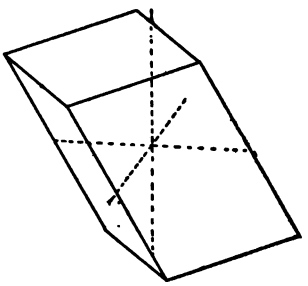


FIG. 58.

That is four planes satisfy the symmetry for the most general form or PRISM, Fig. 58. EXAMPLES.—Pyroxene, orthoclase, gypsum.

THE SIX LIMIT FORMS.

In each class there are six limit forms corresponding to special positions of the faces of the general form. These may be tabulated as follows:

Position of Any Face and its Pole.	Symbol.	Name of Form.	Classes to which Form Belongs.
1. Parallel to *a* and *b*. . . . . Poles projected* on the primitive circle	{001}	PINACOID, Fig. 59. (Basal Pinacoid.)	3, —, 5.
		BASAL PLANE. One face of Fig. 59.	—, 4, —.
2. Parallel to *a* and *c* . . . . Poles projected at centre . .	{010}	PINACOID, Fig. 60. (Clino Pinacoid.)	—, 4, 5.
		PLANE, One face of Fig. 60.	3, —, —.
. Parallel to *b* and *c* . . . . Poles at intersections of primitive circle and horizontal diameter	{100}	PINACOID, Fig. 61. (Ortho Pinacoid.)	3, —, 5.
		PLANE, One face of Fig. 61.	—, 4, —.
		PRISM, Fig. 62.	
4. Parallel to *a* Poles are on diameter from (001) . . .	{0*kl*}	(Clino Dome.)	—, —, 5.
		DOME, Fig. 65.	—, 4, —.
		SPHENOID, Fig. 67.	3, —, —.
5. Parallel to *b* Poles are on primitive circle.	{*h*0*l*}	PINACOID, Fig. 63. (Hemi Ortho Dome.)	3, —, 5.
		PLANE, One face of Fig. 63.	—, 4, —.
6. Parallel to *c* Poles are on Horizontal diameter . . .	{*hk*0}	PRISM, Fig. 64. (Monoclinic Prism.)	—, —, 5.
		DOME, Fig. 66.	—, 4, —.
		SPHENOID, Fig. 68.	3, —, —.

* Plane of projection the pinacoid (010).

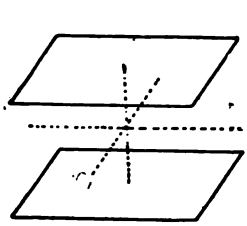


FIG. 59.

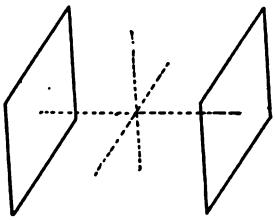


FIG. 60.

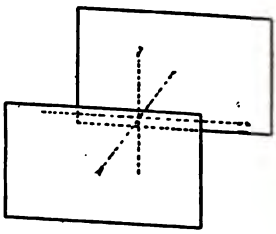


FIG. 61.

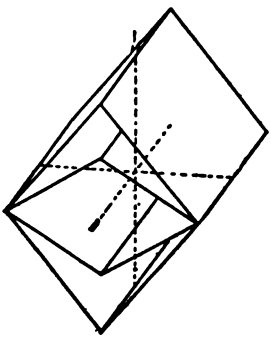


FIG. 62.

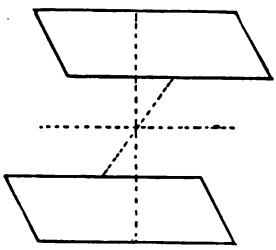


FIG. 63.

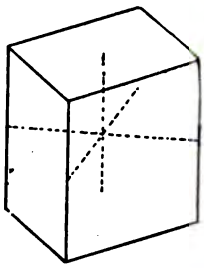


FIG. 64.

LIMIT FORMS OF CLASS 5.

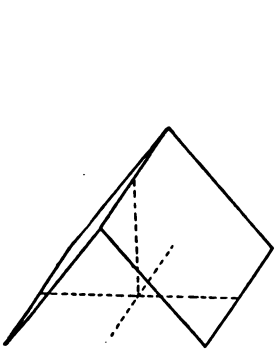


FIG. 65.

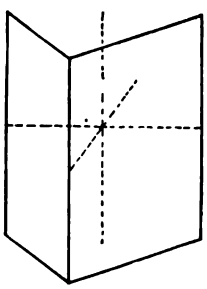


FIG. 66.

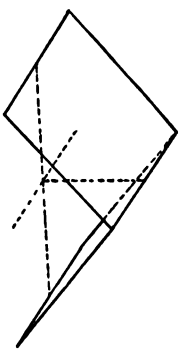


FIG. 67.

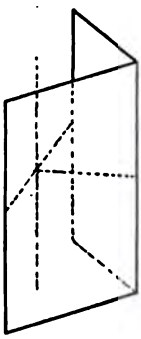


FIG. 68.

OTHER LIMIT FORMS WHICH ARE NEW SHAPES.

PROJECTION AND CALCULATION OF MONOCLINIC FORMS.

The plane of projection may be the pinacoid (010), which is a plane of symmetry in classes 4 and 5, when the poles of all

planes in the zone of b will lie in the primitive circle as given in preceding table. Or the projection may be made, as in the triclinic system, upon a plane normal to the vertical axis, in which case the poles of planes in the zone of b will be projected on the vertical diameter as described in example, p. 287.

The poles will be found as in the triclinic system.

When a plane of symmetry appears as a diameter in the projection, all poles and indices will be symmetrical to this diameter.

DETERMINATION OF ELEMENTS.

In Fig. 29, p. 278, B and Y will coincide and BC, AB and t become 90°. Then $AC=\beta$. In the spherical triangle rst,

$$\cos tr = \frac{\cos s}{\sin r};\ \cos ts = \frac{\cos r}{\sin s};\ \frac{OL}{OK} = \frac{\cos ts}{\sin ts} = \cot ts$$

and $\dfrac{OL}{OH} = \dfrac{\sin(180°-AC-tr)}{\sin tr}$. If P is the parametral plane, $OH:OK:OL = a:b:c$, if not, $a = OH.h$, $b = OK.k$, $c = OL.l$. That is three angles suffice for the determination of the elements.

TO DETERMINE THE POSITION OF ANY POLE P.

Using notation of Fig. 69,

$$\frac{b}{k}\cot PB = \frac{a}{h}\sin CK = \frac{c}{l}\sin AK;$$

$$\frac{\sin CK}{\sin AK} = \frac{ch}{al};\ \frac{h}{l} = \frac{\sin AD}{\sin CD}\cdot\frac{\sin CK}{\sin AK},$$

$$\frac{k}{l} = \frac{\sin AD}{\sin AK}\cdot\frac{\tan OB}{\tan PB};\ \cot AK - \cot AC =$$

$$\frac{h}{l}(\cot AD - \cot AC);\ \cos PA = \sin PB$$

$$\cos AK;\ \cos PC = \sin PB\ \cos CK$$

$$\tan PB = \frac{l}{k}\frac{\sin AD}{\sin AK}\tan OB.$$

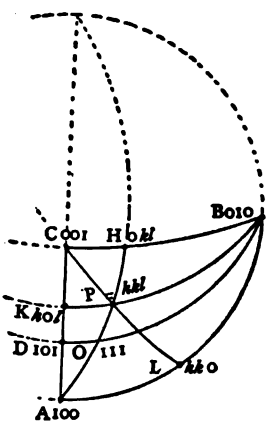


FIG. 69.

Because B is pole of zone circle AA', $CK = PBC$, $AK = PBA$ and $CK = 180° - (PBA + CA')$, that is the sines and cosines of these angles may be substituted for those of the arcs in any of the formulæ above.

To Find the Arc Joining two Poles, P and P'.

Proceed as in triclinic, p. 390.

ORTHORHOMBIC SYSTEM.

All forms in this system must be referable to three nonequivalent axes, Fig. 70, at right angles to each other. The three axes are physically of equal importance, any one may be chosen as c, the vertical; the longer of the other two will be the macro or b axis; the shorter axis (from front to back) the brachy or a axis. There are as many series of forms possible as there are irrational values for $\frac{a}{b}$ and $\frac{c}{b}$.

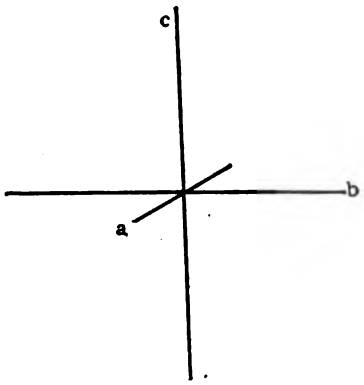


Fig. 70.

6. Class of the Rhombic Bisphenoid.

With three axes of binary symmetry at right angles to each other. As shown in the projection, Fig. 71, four faces satisfy the symmetry of the most general form or Rhombic Bisphenoid, Fig. 72. Example.—Epsomite.

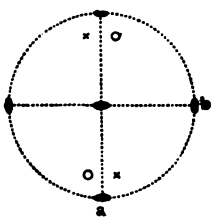


Fig. 71.

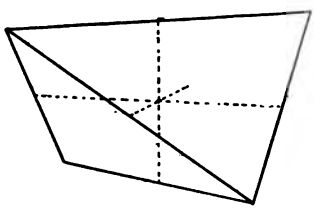


Fig. 72.

7. Class of the Rhombic Pyramid.

With two planes of symmetry perpendicular to each other and intersecting in an axis of binary symmetry. As shown in the projection, Fig. 73, four faces satisfy the symmetry of the most general form or Rhombic Pyramid, Fig. 74. Examples.—Calamine, struvite.

* Story-Maskelyne's *Crystallography*, p. 436 and Groth's *Phys. Kryst.*, p. 578.

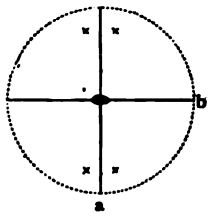


FIG. 73.

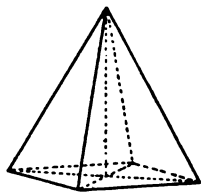


FIG. 74.

8. CLASS OF THE RHOMBIC BIPYRAMID.

With three planes of symmetry at right angles to each other which intersect in three axes of binary symmetry. These are shown in Fig. 75, and the planes divide space into eight octants, shown in projection, Fig. 76, as four trirectangular spherical triangles.

Any upper face corresponding to a pole × in the projection would, by rotation of 180° around the vertical binary axis, coincide with an upper face in the alternate octant, these reflected in the vertical symmetry planes coincide with two other upper faces and the four reflected in the horizontal plane coincide with four lower planes the poles of which are marked by circles. Since h, k and l retain a constant order, there can be sign permutations only corresponding to one plane in each octant.

The symmetry of the class is therefore satisfied by eight faces for the most general form or RHOMBIC BIPYRAMID, Fig. 77.* EXAMPLES.—Aragonite, marcasite, barite.

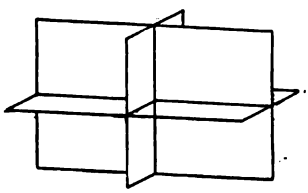


FIG. 75.

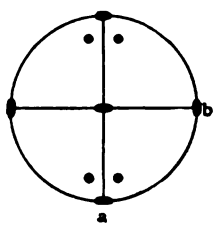


FIG. 76.

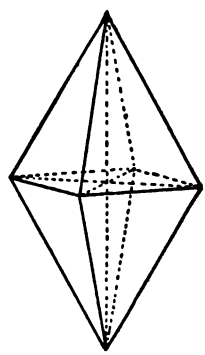


FIG. 77.

*There may be many different pyramids in a series with rational indices hkl which may be all equal, any two equal or all unequal.

The Six Limit Forms.

In each class there are six limit forms corresponding to special positions of the faces of the general form. These may be tabulated as follows:

Position of Any Face and its Pole.	Symbol*	Name of Form.	Classes to which Form Belongs.
1. Parallel to a and b. . . . . Poles are projected at center.	{001}	Basal Pinacoid, Fig. 78. Basal Plane. one face of Fig 78.	6, —, 8. —, 7, —.
2. Parallel to a and c. . . . . Poles are at intersections of b axis and primitive circle	{010}	Pinacoid, Fig. 79. (Brachy Pinacoid).	6, 7, 8.
3. Parallel to b and c . . . . Poles are at intersections of a axis and primitive circle	{100}	Pinacoid, Fig. 80. (Macro Pinacoid).	6, 7, 8.
4. Parallel to a. Poles are on the b axis	{0kl}	Prism, Fig. 81. (Brachy Dome). Dome, Fig. 84.	6, —, 8. —, 7, —.
5. Parallel to b. Poles are on the a axis	{h0l}	Prism, Fig. 82. (Macro Dome). Dome, Fig. 85.	6, —, 8. —, 7, —.
6. Parallel to c. Poles are on the primitive circle . . .	{hk0}	Prism, Fig. 83. (Rhombic Prism).	6, 7, 8.

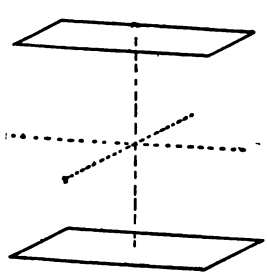


Fig. 78.

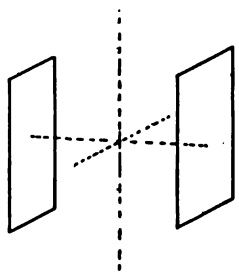


Fig. 79.

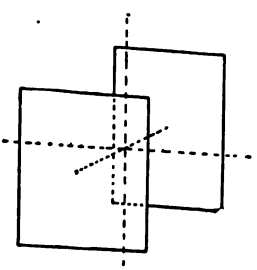


Fig. 80.

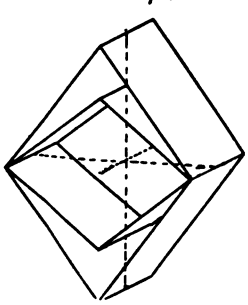


Fig. 81.

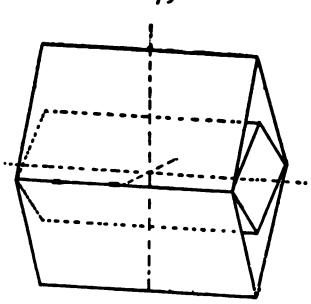


Fig 82.

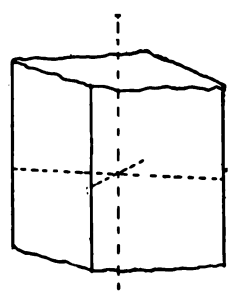


Fig. 83

Limit Forms of Class 8.

* To obtain type symbols. The order is invariably hkl with reference to a, b, c Any may become zero.

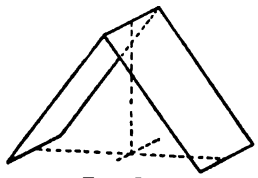


FIG. 84.

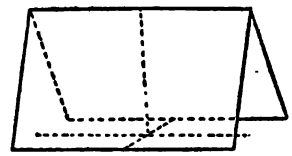


FIG. 85.

OTHER LIMIT FORMS WHICH ARE NEW SHAPES.

PROJECTION AND CALCULATION OF ORTHORHOMBIC FORMS.

The pinacoid (001) is usually selected as the plane of projection. The poles are as in the table and their exact positions usually result from the intersections of known zones or by Problem 3, p. 286. It is sometimes convenient to calculate the position of a plane (*hk*0) corresponding to the plane (*hkl*), lay off this on the primitive circle thus determining the zone [*hk*0 001].

CALCULATION OF ELEMENTS.

The interaxial angles are all right angles.

In the spherical triangle *rst*, $t = 90°$, $r = hkl : 010$, $s = hkl : 100$ Substituting in formulæ p. 394.

$$\cos tr = \frac{\cos s}{\sin r};\ \cos ts = \frac{\cos r}{\sin s},\ \frac{OL}{OK} = \cot ts,\ \frac{OL}{OH} = \cot tr$$

$$a = OH.h,\ b = OK.k,\ c = OL.l.$$

Also, $a = \tan \frac{1}{2} (100 : \bar{1}10)$ and $c = \tan \frac{1}{2} (011 : 0\bar{1}1)$

$$= a \tan \tfrac{1}{2} (101 : \bar{1}01).$$

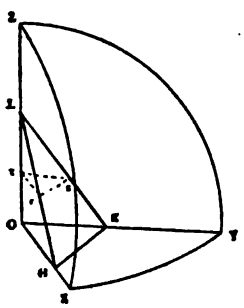


FIG. 86.

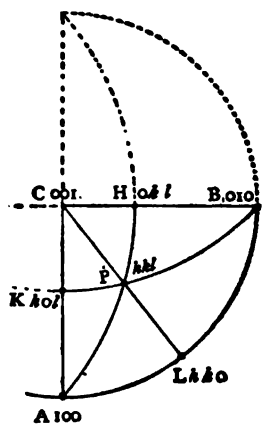


FIG. 87.

GENERAL EQUATION BETWEEN AXES AND INDICES.

$$\frac{a}{h}\cos PA = \frac{b}{k}\cos PB, = \frac{c}{l}\cos PC.$$

TO DETERMINE* ANY POLE P.

$$\cot PA = \frac{hb}{ka}\cos PAB = \frac{hc}{la}\cos PAC = \frac{bc}{a}\frac{h}{\sqrt{c^2k^2+b^2l^2}}$$

$$\cot PB = \frac{kc}{lb}\cos PBC = \frac{ka}{hb}\cos PBA = \frac{ca}{b}\frac{k}{\sqrt{a^2l^2+c^2h^2}}$$

$$\cot PC = \frac{la}{hc}\cos PCA = \frac{lb}{kc}\cos PCB = \frac{ab}{c}\frac{l}{\sqrt{b^2h^2+a^2k^2}}$$

$$\tan PCA = \frac{ka}{bh},\ \tan PBC = \frac{hc}{la},\ \tan PAB = \frac{lb}{kc}$$

For Unit Plane O

$$a : b : c = \cos OB \cos OC : \cos OC \cos OA : \cos OA \cos OB.$$

TO FIND THE ARC JOINING ANY TWO POLES P and P'

Let S denote $h^2b^2c^2 + k^2c^2a^2 + l^2a^2b^2$, S' a similar quantity from indices $h'k'l'$ of second pole.

$$\cos PP' = \frac{hh'b^2c^2+kk'c^2a^2+ll'a^2b^2}{\sqrt{SS'}}$$

If $P' = A, B, C, H, K$ or L of Fig. 87

$$\cos PA = \sin PH = \frac{hbc}{\sqrt{S}},\quad \cos PB = \sin PK = \frac{kca}{\sqrt{S}},$$

$$\cos PC = \sin PL = \frac{lab}{\sqrt{S}}$$

If P' is a face of the same form†

$$\tan PCA = \frac{k}{h}a;\ \tan\tfrac{1}{2}(hkl) : (hk\bar{l}) = \frac{a}{c}\cdot\frac{l}{h}\cos PCA$$

$$\sin\tfrac{1}{2}(hkl) : (h\bar{k}l) = \cos\tfrac{1}{2}(hkl) : (hk\bar{l})\cdot\cos PCA$$

$$\sin\tfrac{1}{2}(hkl) : (\bar{h}kl) = \cos\tfrac{1}{2}(hkl) : (hk\bar{l})\sin PCA.$$

TANGENT RELATION BETWEEN $hkl = P$, and $h'k'l = P'$ which lie in a zone with A, B or C.

$$\frac{h'}{h}\cdot\frac{\tan P'A}{\tan PA} = \frac{k'}{k} = \frac{l'}{l};\ \frac{k'}{k}\frac{\tan P'B}{\tan PB} = \frac{l'}{l} = \frac{h'}{h};\ \frac{l'}{l}\cdot\frac{\tan P'C}{\tan PC} = \frac{h'}{h} = \frac{k'}{k}$$

* Miller's *Crystallography*, p. 79, and Story-Maskelyne's *Crystallography*, p. 443.
† Groth, *Phys. Kryst.*, p. 574.

TETRAGONAL SYSTEM.

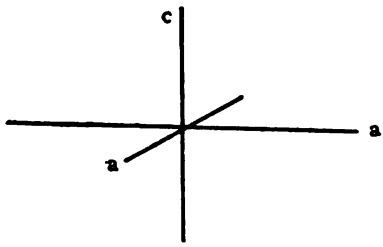


FIG. 88.

All forms of this system must be referable to two equivalent axes, a, at 90° to each other, Fig. 88, and the axis c, conventionally vertical, at 90° to both.

The forms possible on crystals of the same substance can all be referred to one value of $\frac{c}{a}$.

9. CLASS OF THE THIRD ORDER BISPHENOID.

With composite symmetry to a quaternary axis and a plane at right angles thereto. As shown in the projection, Fig. 89, four faces satisfy the symmetry for the most general form or TETRAGONAL BISPHENOID OF THIRD ORDER, Fig. 90. No examples are known.

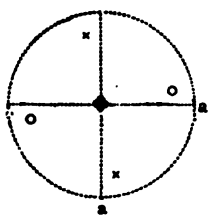


FIG. 89.

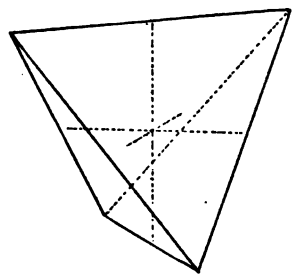


FIG. 90.

10. CLASS OF THE TETRAGONAL PYRAMID OF THIRD ORDER.

With one axis of quaternary symmetry. As shown in the stereographic projection, Fig. 91, four faces satisfy the symmetry for the most general form or TETRAGONAL PYRAMID OF THIRD ORDER, Fig. 92. EXAMPLE.—Wulfenite.

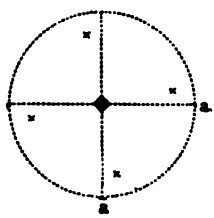


FIG. 91.

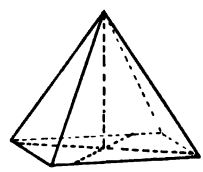


FIG. 92.

11. Scalenohedral Class.

With two planes of symmetry at right angles to each other and intersecting in an axis of quaternary symmetry. Also two axes of binary symmetry midway between the planes. As shown in the projection, Fig. 93, eight faces satisfy the symmetry for the most general form or Scalenohedron, Fig. 94. Example.—Chalcopyrite.

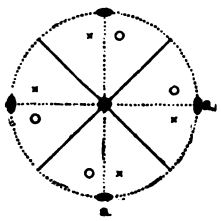


Fig. 93.

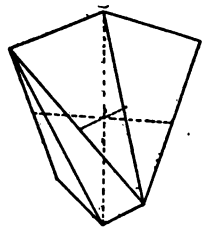


Fig. 94.

12. Trapezohedral Class.

Without planes of symmetry, but with the five axes of Class 15. As shown in the projection, Fig. 95, eight faces satisfy the symmetry for the most general form or Trapezohedron, Fig. 96. Example.—Nickel sulphate, $NiSO_4.6H_2O$.

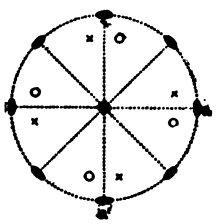


Fig. 95.

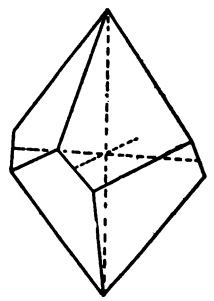


Fig. 96.

13. Class of the Tetragonal Bipyramid of Third Order.

With one horizontal plane of symmetry and one vertical axis of quaternary symmetry. As shown in the projection, Fig. 97, eight faces satisfy the symmetry for the most general form or Tetragonal Bipyramid of Third Order, Fig. 98. Example.—Scheelite.

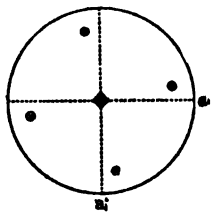


FIG. 97.

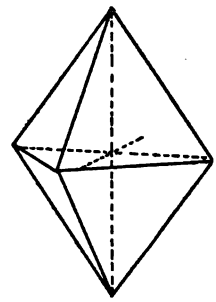


FIG. 98.

14. CLASS OF THE DITETRAGONAL PYRAMID.

With four vertical planes of symmetry intersecting in an axis of quaternary symmetry. As shown in the projection, Fig. 99, the essential change from Class 15 is the omission of the plane of symmetry normal to the quaternary axis. The general form is therefore geometrically like the upper or lower half of Fig. 103. Fig. 100 shows the six-faced most general form or DITETRAGONAL PYRAMID. EXAMPLE.—Silver fluoride, $AgF.H_2O$.

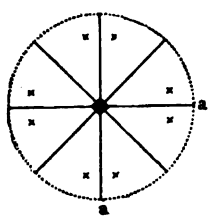


FIG. 99.

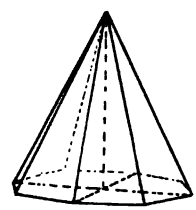


FIG. 100.

15. CLASS OF THE DITETRAGONAL BIPYRAMID.

With four planes of symmetry at 45° to each other, which intersect in an axis of quaternary symmetry, and one plane normal to these which intersects the four planes in axes of binary symmetry.

The planes divide space into sixteen sections, Fig. 101 shown in the projection, Fig. 102, as eight birectangular spherical triangles with angles at the center of 45°. Any upper face corresponding to a pole ×, by rotations of 90° coincides successively with three other upper faces. These four reflected in a vertical plane coincide with four others and the eight reflected in a horizontal plane coincide with eight lower faces marked with a circle.

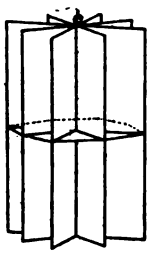


FIG. 101.

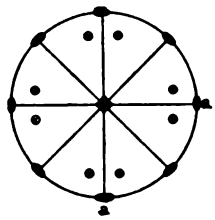


FIG. 102.

FIG. 103.

Since *l* remains with the third axis, the letter permutations are only *hkl* and *khl*. Each of these is subject to eight permutations in sign +++, +−+, −−+, −++, ++−, +−−, −−−, −+−.

Both symmetry and permutations show that there must be in this class sixteen faces in the most general form or DITETRAGONAL BIPYRAMID Fig. 103. EXAMPLES.—Zircon, cassiterite, rutile.

LIMIT FORMS OF CLASS 15.

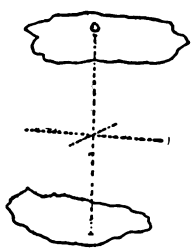


FIG. 104.

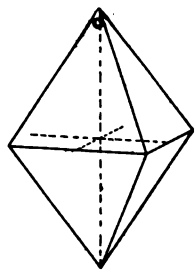


FIG. 105.

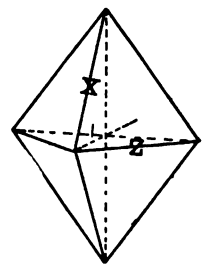


FIG. 106.

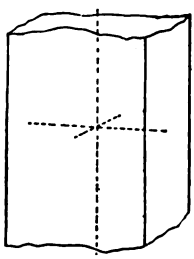


FIG. 107.

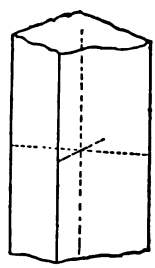


FIG. 108.

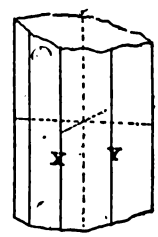


FIG. 109.

THE SIX LIMIT FORMS.

In each class there are six limit forms corresponding to special positions of the faces of the general form. These may be tabulated as follows:

Position of any Face and its Pole.	Symbol*	Name of Form.	Classes to which the Form belongs.
1. Intersects the vertical axis and is parallel to both basal axes. Poles are projected at the center.	{001}	BASAL PINACOID, Fig. 104.	15, —, 13, 12, 11, —, 9.
		BASAL PLANE, one face of Fig. 104.	—, 14, —, —, —, 10, —.
2. Intersects the vertical axis and is parallel to one basal axis. Poles are on axial diameters.	{*h*0*l*}	TETRAGONAL BIPYRAMID, SECOND ORDER, Fig. 105.	15, —, 13, 12, 11, —, —.
		TETRAGONAL PYRAMID, SECOND ORDER, Fig. 113.	—, 14, —, —, —, 10, —.
		TETRAGONAL BISPHENOID, SECOND ORDER, Fig. 111.	—, —, —, —, —, —, 9.
3. Intersects the vertical axis and is equally inclined to both basal axes. Poles are on diagonal diameters.	{*hhl*}	TETRAGONAL BIPYRAMID, FIRST ORDER, Fig. 106.	15, —, 13, 12, —, —, —.
		TETRAGONAL PYRAMID, FIRST ORDER, Fig. 114.	—, 14, —, —, —, 10, —.
		TETRAGONAL BISPHENOID, FIRST ORDER, Fig. 110.	—, —, —, —, 11, —, 9.
4. Parallel to the vertical axis and to one basal axis. Poles are at intersections of primitive circle and axial diameters.	{100}	TETRAGONAL PRISM, SECOND ORDER, Fig. 107.	15, 14, 13, 12, 11, 10, 9.
5. Parallel to the vertical axis and equally inclined to the basal axes. Poles are at intersections of primitive circle and diagonal diameters.	{110}	TETRAGONAL PRISM, FIRST ORDER, Fig. 108.	15, 14, 13, 12, 11, 10, 9.
6. Parallel to the vertical axis and unequally inclined to the basal axes. Poles are on the primitive circle.	{*hk*0}	DITETRAGONAL PRISM, Fig. 109.	15, 14, —, 12, 11, —, —.
		TETRAGONAL PRISM, THIRD ORDER, Fig. 112.	—, —, 13, —, —, 10, 9.

* The first and second indices will be *h* and *k* or both *h* if equal, or *ho* if the face is parallel to one basal axis. The third symbol will be *i* or *o* as the face intersects or is parallel to the vertical axis. These must be reduced to simplest form.

LIMIT FORMS OF CLASS 15.

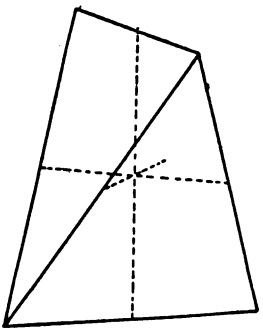


FIG. 110.

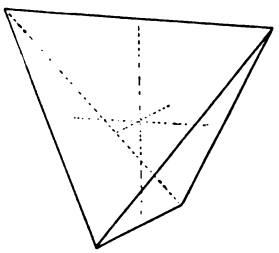


FIG. 111.

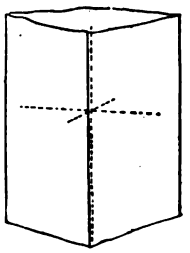


FIG. 112.

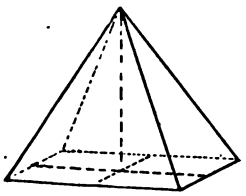


FIG. 113.

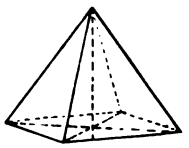


FIG. 114.

OTHER LIMIT FORMS WHICH ARE NEW SHAPES.

PROJECTION AND CALCULATION OF TETRAGONAL FORMS.

The basal pinacoid is usually selected as the plane of projection, the poles lying as stated in the table. On p. 287, Fig. 36, is described the projection of the poles of a crystal of cassiterite.

DETERMINATION OF ELEMENTS.

In Fig. 86, $\cos tr = \frac{\cos s}{\sin r}$ and $\frac{OL}{OH} = \cot tr$. $c = OL.l$

Also in Fig. 115 if $hhl = F$.

$$c = \tan FC \cos 45° = \tan KC$$

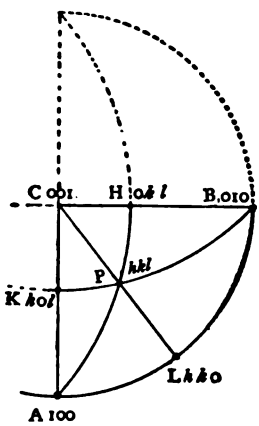
$$\sin KC = \tan KF \cot 45$$

$$c = \frac{l}{\sqrt{h^2+k^2}} \tan PC$$

TO DETERMINE POSITION OF ANY POLE* P.

$$\cot PA = \tan PH = \frac{h}{k} \cos PAB$$

$$= \frac{hc}{la} \cos PAC = \frac{ch}{\sqrt{c^2k^2+a^2l^2}}$$



* Miller's *Crystallography*, p. 44, Story-Maskelyne's *Crystallography*, p. 449.

$$\cot PB = \tan PK = \frac{k}{h}\cos PBA = \frac{kc}{la}\cos PBC = \frac{kc}{\sqrt{a^2l^2+c^2h^2}}$$

$$\cot PC = \tan PL = \frac{la}{hc}\cos PCA = \frac{la}{kc}\cos PCB = \frac{la}{\sqrt{c^2(h^2+k^2)}}$$

GENERAL EQUATION BETWEEN AXES AND INDICES.

$$\frac{a}{h}\cos PA = \frac{a}{k}\cos PB = \frac{c}{l}\cos P.$$

FORMULA FOR ANGLE BETWEEN TWO PLANES.

$$\cos PP' = \frac{c^2(hh'+kk')+a^2ll'}{\sqrt{c^2(h^2+k^2)+a^2l^2}\ \sqrt{c^2(h'^2+k'^2)+a^2l'^2}}$$

Formulæ for angle between two faces of same form are as on p. 399.

ANGLE $P'C$ WHEN PC KNOWN

$$\frac{l'}{\sqrt{h'^2+k'^2}}\tan P'C = \frac{l}{\sqrt{h^2+k^2}}\tan PC.$$

HEXAGONAL SYSTEM.

All forms in this system must be referable to three equivalent axes a in one plane at 60° to each other and a fourth axis c normal to these, conventionally placed vertically. Fig. 116.

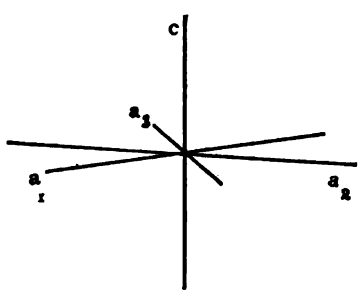


FIG. 116.

The system comprises two grand divisions. The Hexagonal division with five classes in which the fourth axis is an axis of senary symmetry. The Rhombohedral division with seven classes in which this axis is an axis of ternary symmetry.

The vertical and basal axes being non-equivalent, the ratio of the parameters $\frac{c}{a}$ is always an irrational number and for each different ratio a different series of forms exists, one series only being capable of occurrence on the crystals of the same substance.

The basal axes are most conveniently considered in the order of

the figure, for then* the third index is always the algebraic sum of the first and second.

THE RHOMBOHEDRAL DIVISION.

16. Class of the Trigonal Pyramid of Third Order.

Without planes of symmetry, but with an axis of ternary symmetry. As shown in projection, Fig. 117, the symmetry is satisfied by three faces for the general form, or Trigonal Pyramid of Third Order, Fig. 118. Examples.—Sodium periodate $NaIO_4.3H_2O$.

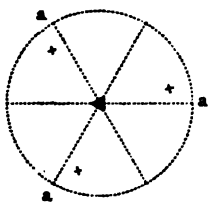


Fig. 117.

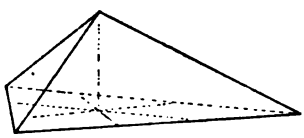


Fig. 118.

17. Class of Rhombohedron of the Third Order.

With composite symmetry to a ternary axis and a plane at right angles thereto. As shown in the stereographic projection, Fig. 119, the symmetry is satisfied by six faces for the most general form or Rhombohedron of the Third Order, Fig. 120. Examples.—Dioptase, phenacite.

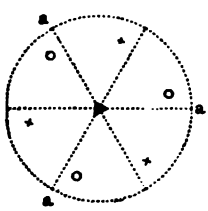


Fig. 119.

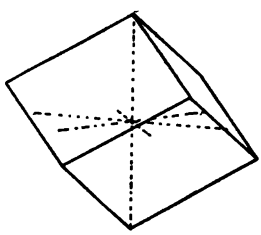


Fig. 120.

18. Class of the Trigonal Trapezohedron.

Without planes of symmetry, but with the four axes of symmetry of Class 22. As shown in projection, Fig. 121, the symmetry is satisfied by six planes for the general form, or Trigonal Trapezohedron, Fig. 122. Examples.—Quartz, cinnabar.

* Simple proof in Bauerman's Systematic Mineralogy, p. 76.

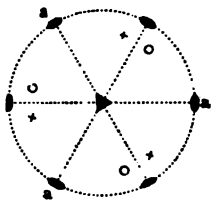


FIG. 121.

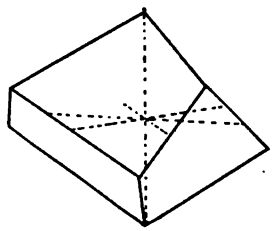


FIG. 122.

19. CLASS OF THE TRIGONAL BIPYRAMID OF THIRD ORDER.

With one plane of symmetry at right angles to the axis of ternary symmetry. As shown in the projection, Fig. 123, the symmetry is satisfied by six planes for the most general form, or TRIGONAL BIPYRAMID OF THIRD ORDER, Fig. 124. No examples are known.

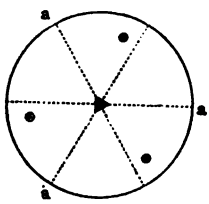


FIG. 123.

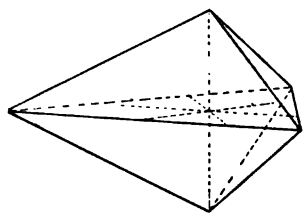


FIG. 124.

20. CLASS OF THE DITRIGONAL PYRAMID.

With three planes of symmetry at 60° to each other which intersect in the axis of ternary symmetry. These forms are geometrically the upper or lower halves of those of Class 22. As shown in projection, Fig. 125, the symmetry is satisfied by six planes for the most general form, or DITRIGONAL PYRAMID, Fig. 126. EXAMPLES.—Tourmaline, proustite, pyrargyrite.

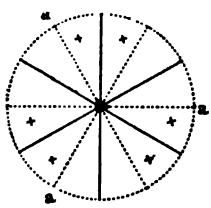


FIG. 125.

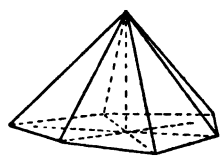


FIG. 126.

21. CLASS OF THE DITRIGONAL SCALENOHEDRON.

With three planes of symmetry at 60° to each other and intersecting in an axis of ternary symmetry, and three axes of binary

symmetry bisecting the angles between the planes. As shown in projection, Fig. 127, the symmetry is satisfied by twelve faces for the most general form, or DITRIGONAL SCALENOHEDRON, Fig. 128. EXAMPLES.—Calcite, hematite, corundum.

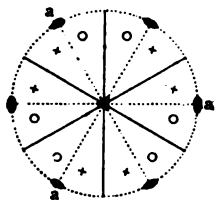


FIG. 127.

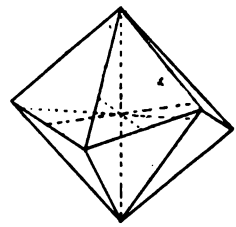


FIG. 128.

22. CLASS OF THE DITRIGONAL BIPYRAMID.

With three planes of symmetry at 60° to each other which intersect in an axis of ternary symmetry and one plane normal to these which intersects the others in axes of binary symmetry. The planes, Fig. 129, divide space into twelve equal parts, shown in projection, Fig. 130, as six birectangular spherical triangles with angles at the center 60°.

Any upper face, corresponding to a pole × in one of the triangles, would by rotations of 120° around the ternary axis coincide with two other upper faces. Each of these by reflection in a vertical plane of symmetry coincides with another face and the six by reflection in the horizontal plane of symmetry coincide with six lower faces, the poles of which are indicated by circles.

The symmetry of the class is satisfied by twelve faces for the most general form or DITRIGONAL BIPYRAMID, Fig. 131. No examples are known.

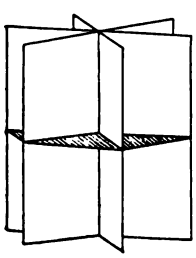


FIG. 129.

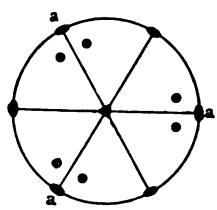


FIG. 130.

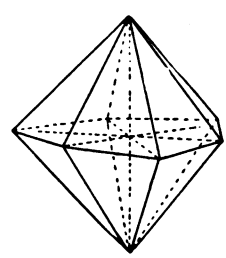


FIG. 131.

The Six Limit Forms.

In each class there are six limit forms corresponding to special positions of the faces of the general form. These may be tabulated as follows:

Position of any Face and its Pole.	Symbols	Name of Form.	Classes to which the form belongs.
1. Parallel to all basal axes. Poles projected at the centre.	{0001}	Basal Pinacoid, Fig. 153.	22, 21, —, 19, 18, 17, —
		Basal Plane, one plane of Fig. 153.	—, —, 20, —, —, —, 16.
2. Oblique to the vertical axis but parallel to one basal axis. Poles are on the interaxial diameters.	{$h0\bar{h}i$}	Trigonal Bipyramid First Order, Fig. 132.	22, —, —, 19, —, —, —.
		Rhombohedron First Order, Fig. 135.	—, 21, —, —, 18, 17, —.
		Trigonal Pyramid First Order, Fig. 136.	—, —, 20, —, —, —, 16.
3. Oblique to the vertical axis and equally inclined to alternate basal axes. Poles are on the axes.	{$hh\bar{2}hi$}	Hexagonal Bipyramid Second Order, Fig. 155.	22, 21, —, —, —, —, —.
		Hexagonal Pyramid Second Order, Fig. 160.	—, —, 20, —, —, —, —.
		Trigonal Bipyramid Second Order, Fig. 137.	—, —, —, 19, 18, —, —.
		Rhombohedron Second Order, Fig. 140.	—, —, —, —, —, 17, —.
		Trigonal Pyramid Second Order, Fig. 141.	—, —, —, —, —, —, 16.
4. Parallel to the vertical axis and to one basal axis. Poles are at intersections of primitive circle and interaxial diameters.	{$10\bar{1}0$}	Trigonal Prism First Order, Fig. 133.	22, 21, 20, 19, —, —, 16.
		Hexagonal Prism First Order, Fig. 156.	—, —, —, —, 18, 17, —.
5. Parallel to the vertical axis and equally inclined to alternate basal axes. Poles are at intersections of axes and primitive circle.	{$11\bar{2}0$}	Hexagonal Prism Second Order, Fig. 157.	22, 21, 20, —, 18, 17, —.
		Trigonal Prism Second Order, Fig. 138.	—, —, —, 19, —, —, 16.
6. Parallel to the vertical and unequally inclined to all basal axes. Poles are on primitive circle.	{$hk\bar{1}0$}	Ditrigonal Prism, Fig. 134.	22, —, 20, —, 81, —, —.
		Dihexagonal Prism, Fig. 158.	—, 21, —, —, —, —, —.
		Trigonal Prism Third Order, Fig. 139.	—, —, —, 19, —, —, 16.
		Hexagonal Prism Third Order, Fig. 161.	—, —, —, —, —, 17, —.

* See footnote under hexagonal division, p. 414.

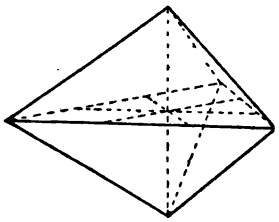


FIG. 132.

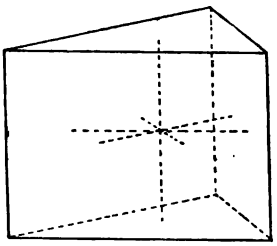


FIG. 133.

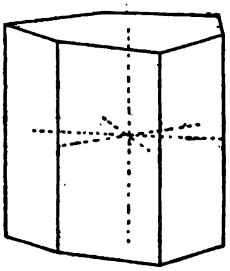


FIG. 134.

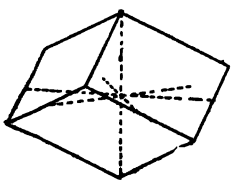


FIG. 135.

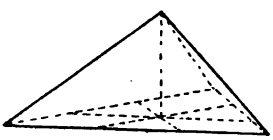


FIG. 136.

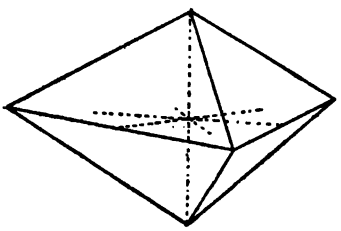


FIG. 137.

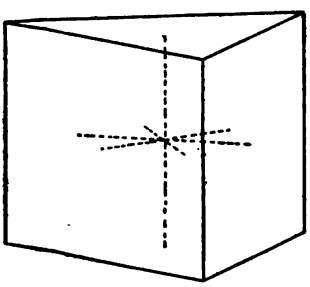


FIG. 138.

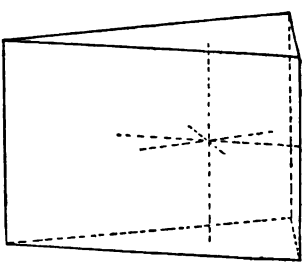


FIG. 139.

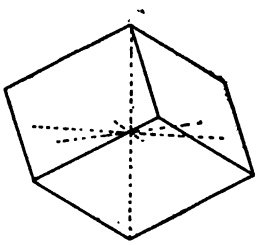


FIG. 140.

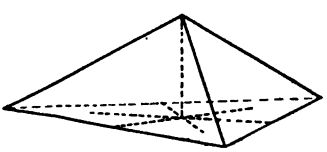


FIG. 141.

LIMIT FORMS IN RHOMBOHEDRAL DIVISION WHICH ARE GEOMETRICALLY SHAPES NOT INCLUDED IN HEXAGONAL DIVISION.

THE HEXAGONAL DIVISION.

23. Class of the Third Order Hexagonal Pyramid.

Without planes of symmetry but with one axis of senary symmetry. As shown in the projection, Fig. 142, six planes satisfy the symmetry of the most general form or Hexagonal Pyramid of Third Order, Fig. 143. Example.—Nephelite.

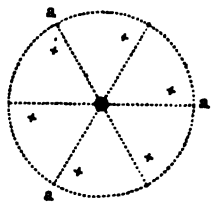


Fig. 142.

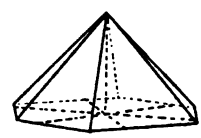


Fig. 143.

24. Class of the Hexagonal Trapezohedron.

Without planes of symmetry but with the seven axes of Class 27. As shown in projection, Fig. 144, twelve faces satisfy the symmetry for the most general form or Hexagonal Trapezohedron, Fig. 145. Example.—$(SbO)_2BaC_4H_4O_6.KNO_3$.

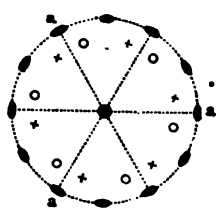


Fig. 144.

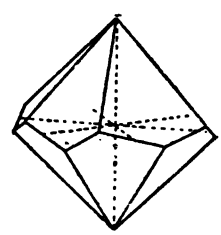


Fig. 145.

25. Class of the Third Order Hexagonal Bipyramid.

With one plane of symmetry normal to the axis of senary symmetry. As shown in projection, Fig. 146, twelve faces satisfy the symmetry for the most general form or Hexagonal Bipyramid of Third Order, Fig. 147. Example.—Apatite, pyromorphite.

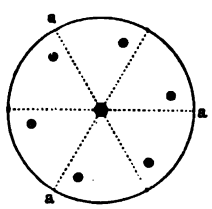


Fig. 146.

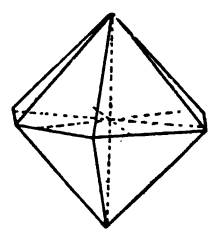


Fig. 147.

26. Class of the Dihexagonal Pyramid.

With six planes of symmetry at 30° to each other and intersecting in the axis of senary symmetry. From the projection, Fig. 148, it is evident that the general form, Fig. 149, or Dihexagonal Pyramid, Fig. 149, is geometrically the upper (or lower) half of the general form, Fig. 152, of the next class.

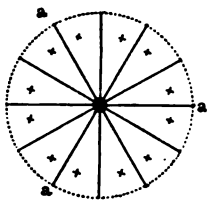


Fig. 148.

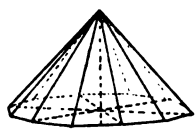


Fig. 149.

27. Class of the Dehexagonal Bipyramid.

With seven planes of symmetry, six being normal to the seventh and at 30° to each other as shown in Fig. 150. The common intersection of six planes of symmetry is the axis of senary symmetry and their intersections with the seventh are axes of binary symmetry.

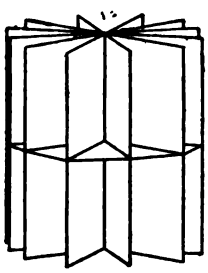


Fig. 150.

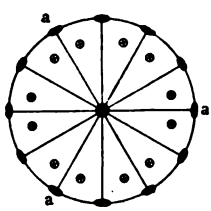


Fig. 151.

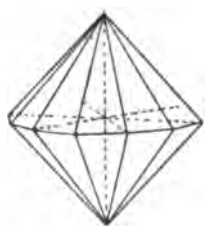


Fig. 152.

In projection, Fig. 151, the planes of symmetry form twelve equal birectangular spherical triangles with angles at the centre, 30°. Any upper face, with a pole marked ×, by rotations of 60° around the senary axis coincides successively with five other upper faces represented by crosses in the alternate triangles. Each of the six reflected in a vertical plane of symmetry coincides with another face and the twelve reflected in the horizontal plane coincide with twelve lower faces represented by circles.

The letter permutations of the general symbol ($hk\bar{i}l$), in which i always must remain in fourth place, are *hkli*, *hlki*, *khli*, *klhi*, *lhki*, *lkhi*, and each may have four sign permutations, $++-+$, $--++$, $++-\leftarrow$ and $--+-$ or twenty-four permutations in all. Projection and permutation both show that the symmetry of the class is satisfied by twenty-four faces for the most general form or DIHEXAGONAL BIPYRAMID, Fig. 152. EXAMPLE.—Beryl.

THE SIX LIMIT FORMS.

In each class there are six limit forms—corresponding to special positions of the faces of the general form. These may be tabulated as follows:

Position of any Face and its Pole.	Symbol*	Name of Form.	Classes to which the form bel'ng's
1. Parallel to all basal axes. Poles projected at the center.	$\{0001\}$	BASAL PINACOID, Fig. 153. BASAL PLANE, one plane of Fig. 153.	27,—,25,24,— —,26,—,—,23.
2. Oblique to the vertical axis but parallel to one basal axis. Poles are on the interaxial diameters.	$\{h0\bar{h}i\}$	HEXAGONAL BIPYRAMID FIRST ORDER, Fig. 154. HEXAGONAL PYRAMID FIRST ORDER, Fig. 159.	27,—,25,24,— —,26,—,—,23.
3. Oblique to the vertical axis and equally inclined to alternate basal axes. Poles are on the axes.	$\{hh2\bar{h}i\}$	HEXAGONAL BIPYRAMID SECOND ORDER, Fig. 155. HEXAGONAL PYRAMID SECOND ORDER, Fig. 160.	27,—,25,24,— —,26,—,—,23.
4. Parallel to the vertical axis and to one basal axis. Poles are at intersections of primitive circle and interaxial diameters.	$\{10\bar{1}0\}$	HEXAGONAL PRISM FIRST ORDER, Fig. 156.	27,26,25,24,23.
5. Parallel to the vertical axis and equally inclined to alternate basal axes. Poles are at the intersections of axes and primitive circle.	$\{11\bar{2}0\}$	HEXAGONAL PRISM SECOND ORDER, Fig. 157.	27,26,25,24,23.
6. Parallel to the vertical but unequally inclined to all basal axes. Poles are on the primitive circle.	$\{hk\bar{l}0\}$	DIHEXAGONAL PRISM, Fig. 158. HEXAGONAL PRISM THIRD ORDER, Fig. 161.	27,26,—,24,— —,—,25,—,23.

* In the type symbols the first and second indices relate to the relative inclination of the faces to the alternate basal axes. If unequally inclined *hk*, if equally inclined *hh*, if parallel to one *ho*. The third index is $\bar{l}$, the algebraic sum of the first and second with the opposite sign.

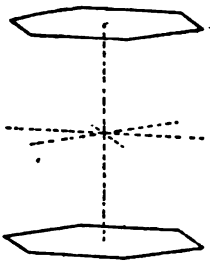


FIG. 153.

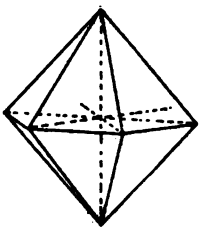


FIG. 154.

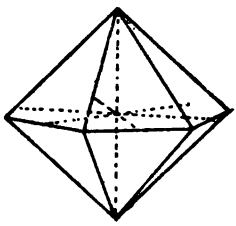


FIG. 155.

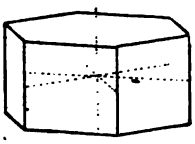


FIG. 156.

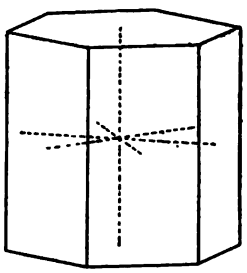


FIG. 157.

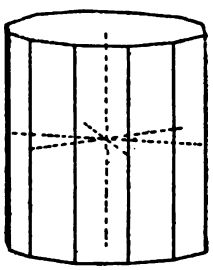


FIG. 158.

LIMIT FORMS OF CLASS 27.

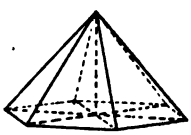


FIG. 159.

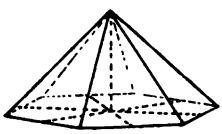


FIG. 160.

LIMIT FORMS GEOMETRICALLY NEW IN THE OTHER CLASSES.

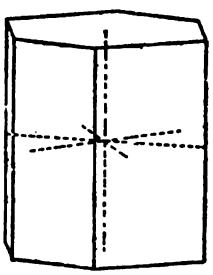


FIG. 161.

PROJECTION AND CALCULATION OF HEXAGONAL AND RHOMBOHEDRAL FORMS.

The basal pinacoid is the plane of projection. The position of the poles are as in the tables, pp. 410 and 414.

The indices of a face truncating an edge of any form are the sum of the indices of the faces forming the edge, for example, the edge between $10\bar{1}1$ and $01\bar{1}1$ is truncated by $11\bar{2}2$.

THE ZONAL RELATIONS

Are calculated from three indices of which one must relate to the vertical axis. For instance, by method of cross multiplication

the zone indices of the planes $hk\bar{i}l, h'k'\bar{i}'l'$ will be determined by hki and $h'k'i'$: $u = ki' - ik'$, $v = ih' - hi'$, $w = hk' - kh'$.

DETERMINATION OF ELEMENTS.

Two equal basal axes at 120° to each other and at right angles to the vertical are sufficient. In Fig. 111 the spherical triangle rst has $t = 120°$.

$$\cos tr = \frac{\cos s + \frac{1}{2}\cos r}{\frac{1}{2}\sin r\sqrt{3}}; \cot tr = \frac{OL}{OH}; c = OL.i$$

or

$$\tan (0001):(1\bar{1}22) = \frac{h}{i} = \frac{c}{a} = c$$

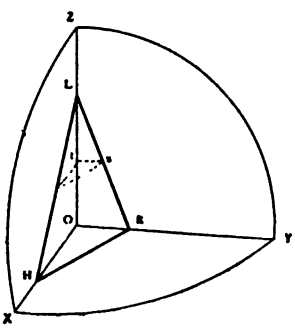


FIG. 162.

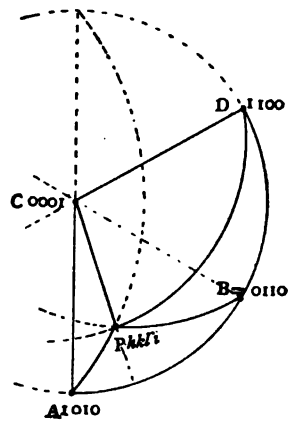


FIG. 163.

TO DETERMINE THE POSITION OF ANY POLE P.

Using notation of Fig. 163 and denoting by M the quantity

$$\sqrt{3i^2 + 4c^2(h^2 + k^2 + hk)}$$

$$\cos PA = \frac{c(2h + k)}{M}, \cos PB = \frac{c(h + 2k)}{M}, \cos PD = \frac{c(k - h)}{M}$$

$$\cos PC = \frac{i\sqrt{3}}{M}$$

TO FIND THE ARC JOINING TWO POLES P AND P'.

$$\cos PP' = \frac{3ii' + 2c^2(hk' + kh' + 2hh' + 2kk')}{MM'}$$

TANGENT PRINCIPLE.

$$\frac{i}{i'} \cdot \frac{\tan PC}{\tan P'C} = \frac{k}{k'} = \frac{h}{h'}$$

THE ISOMETRIC SYSTEM.

All forms in this system must be referrable to three equivalent axes at right angles to each other. The system includes five classes.

28. Class of the Tetartoid.

The forms have seven axes of symmetry but no planes of symmetry. Three of the axes are binary normal to the faces of the hexahedron and four are ternary through diagonally opposite solid angles of the hexahedron.

As shown in the projection Fig. 164, twelve faces in each alternate octant satisfy the symmetry for the most general form or TETARTOID, Fig. 165. EXAMPLES—Sodic chlorate, baric nitrate.

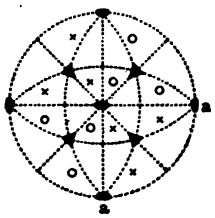


FIG. 164.

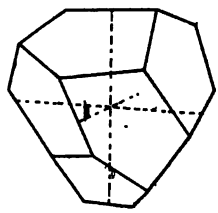


FIG. 165.

29. Class of the Gyroid.

Without planes of symmetry but with all the axes of symmetry of class 32. As shown in the projection Fig. 166, twenty-four faces, three in each octant, satisfy the symmetry for the most general form * or GYROID, Figs. 168 and 167. EXAMPLES.—Halite, sylvite, cuprite.

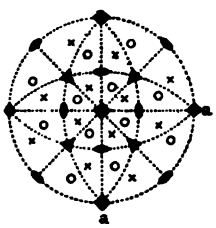


FIG. 166.

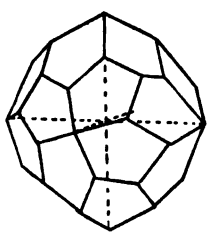


FIG. 167.

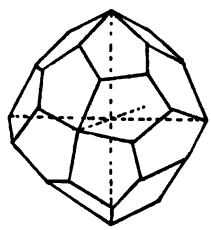


FIG. 168.

*The right form, Fig. 168, and the left form, Fig. 167, are enantimorphic, that is, their elements are equal and the faces of the one are parallel but oppositely placed with respect to those of the other.

30. Class of the Diploid.

The forms have three cubic planes of symmetry, the intersection of these are three axes of binary symmetry and there are four diagonal axes of ternary symmetry.

As shown by the projection, Fig. 169, the symmetry of the class is satisfied by twenty-four faces for the most general form or Diploid, Figs. 170 and 171. Examples—Pyrite, smaltite, cobaltite.

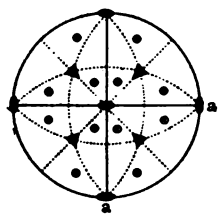


Fig. 169.

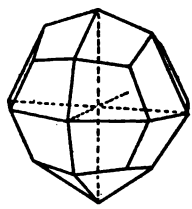


Fig. 170.

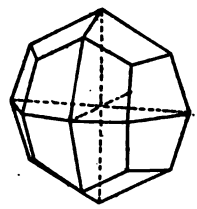


Fig. 171.

31. Class of the Hextetrahedron.

The forms* have the six dodecahedral planes of symmetry of Class 32 and the seven axes of symmetry formed by their intersection. Of the latter, four are ternary and three binary.

As shown in the projection, Fig. 172, the symmetry of this class is satisfied by twenty-four faces for the most general form or Hextetrahedron, Figs. 173 and 174. Examples.—Sphalerite, tetrahedrite, diamond.

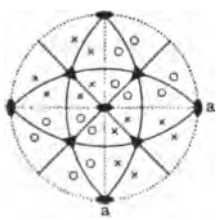


Fig. 172.

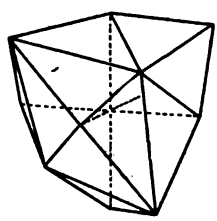


Fig. 173.

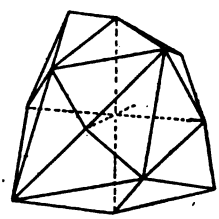


Fig. 174.

32. Class of the Hexoctahedron.

The forms of this class have three planes of symmetry parallel to the faces of the cube and six planes of symmetry through diag-

* The forms of this class exist in pairs which are said to be *congruent*, that is either by a revolution of 90° about an axis may brought into the position of the other. They are distinguished as right and left forms.

onally opposite edges of the cube, that is parallel to the faces of the rhombic dodecahedron Fig. 181.

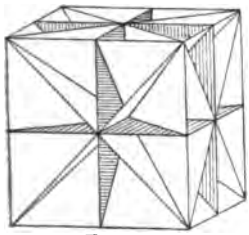


FIG. 175.

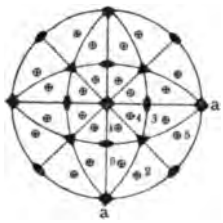


FIG. 176.

FIG. 177.

The intersections of these planes are axes of symmetry; three are quatenary the intersections of the planes parallel the hexahedron; four are ternary, each the intersections of three diagonal planes; and six are binary, each the intersection of a plane of each kind.

These planes and axes of symmetry are shown in stereographic projection, Fig. 176.

The number of faces in the most general form may be determined as follows:—

In any quadrant the pole marked 1 of a face in the upper half of the crystal by rotations of 120° around the ternary axis must coincide successively with faces the poles of which are 2 and 3. These three by reflection in the planes of symmetry must coincide 1 with 4, 2 with 5, 3 with 6. Since there is a vertical axis of quaternary symmetry the entire quadrant must coincide successively pole for pole with the second, third and fourth quadrants and finally the resulting 24 faces reflected in the horizontal plane of symmetry must coincide with 24 lower faces. That is, the form must consist of 48 faces with a pole in each of the right spherical triangles made by the planes of symmetry.

This result could also be reached by considering the possible permutations of letter and sign in the symbol of the general form $\{hkl\}$. The letter permutations are:

$$hkl,\ hlk,\ klh,\ khl,\ lkl,\ lhk.$$

Each of these can undergo eight permutations in sign according to the octant in which the plane occurs.

Upper octants $+\,+\,+,\ -\,+\,+,\ -\,-\,+,\ +\,-\,+,$
Lower octants $+\,+\,-,\ -\,+\,-,\ -\,-\,-,\ +\,-\,-,$

or 48 permutations in all. That is to satisfy the symmetry the most general form or HEXOCTAHEDRON, Fig. 177, must consist of 48 faces six in each octant. EXAMPLES.—Garnet, fluorite, spinel.

THE SIX LIMIT FORMS.

In each class there are six limit forms corresponding to special positions of the faces of the general form. These may be tabulated as follows:

Position of any Face.	Symbol*	Name of Form.	Classes to which Form belongs.
1. Equally inclined to all three axes. Poles on ternary axes.	{111}	OCTAHEDRON, Fig. 178.	32,—,30, 29,—.
		TETRAHEDRON, Fig. 184.	—,31,—,—, 28.
2. Equally inclined to two axes, more nearly parallel the third. Poles are on the short sides of triangles.	{*hhl*}	TRIGONAL TRISOCTAHEDRON, Fig. 179.	32,—,30, 29,—.
		TETRAGONAL TRISTETRAHEDRON, Fig. 185.	—,31,—,—,28.
3. Equally inclined to two axes less nearly parallel the third. Poles are on hypothenuse.	{*hkk*}	TETRAGONAL TRISOCTAHEDRON, Fig. 180.	32,—, 30,29,—.
		TRIGONAL TRISTETRAHEDRON, Fig. 186.	—, 31,—,—,28.
4. Equally inclined to two axes,parallel thethird. Poles at vertices of right angles.	{110}	RHOMBIC DODECAHEDRON, Fig. 181.	32, 31,30,29,28.
5. Unequally inclined to two axes parallel the third. Poles are on the long sides.	{*hko*}	TETRAHEXAHEDRON, Fig. 182.	32,31,—,29,—.
		PENTAGONAL DODECAHEDRON, Fig. 187.	—,—, 30,—,28.
6. Parallel to two axes. Poles are on the quaternary axes.	{100}	HEXAHEDRON, 183.	32,31, 30,29,28.

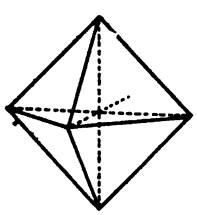


FIG. 178.

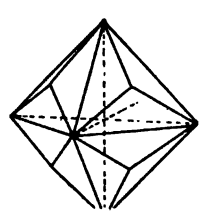


FIG. 179.

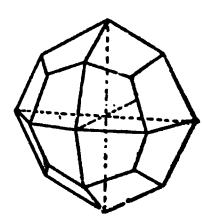


FIG. 180.

* The *type* symbols of the forms are easily obtained without direct reference to the intercepts by noting parallelism and relative nearness to parallelism to the axes. Zero being the symbol of parallelism and conventionally $h > k > l$.

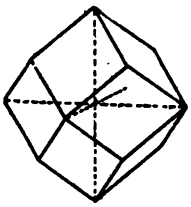


FIG. 181.

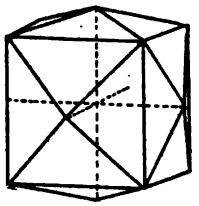


FIG. 182.

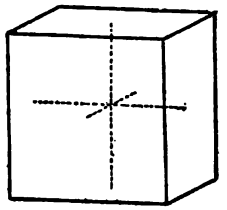


FIG. 183.

LIMIT FORMS OF CLASS 32.

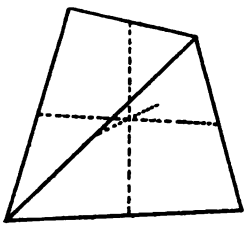


FIG. 184.

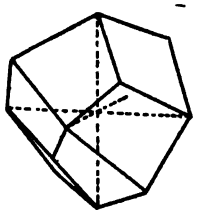


FIG. 185.

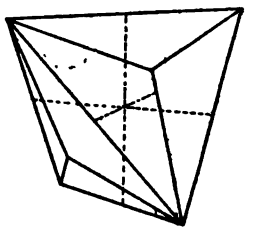


FIG. 186.

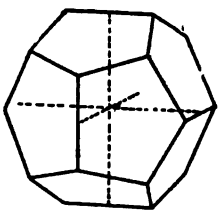


FIG. 187.

LIMIT FORMS GEOMETRICALLY NEW IN THE OTHER CLASSES.

PROJECTION AND CALCULATION* OF ISOMETRIC FORMS.

The forms are usually projected on a cubic face and the poles lie as stated in the table, the positions being usually found by zone intersections. The planes of symmetry divide space into forty-eight similar parts each shown in stereographic projection as a right triangle in which: the hypothenuse (54° 44′), is the angle between a binary and a ternary axis; the longer side (45°) is the half angle between two binary axes; the shorter side (35° 16′) is the half angle between two ternary axes.

CALCULATION OF ELEMENTS.

The parameters are all equal and the angles between the axes are right angles.

* Millers' *Crystallography*, pp. 25; Story-Maskelyne's *Crystallography*, p. 453.

GENERAL EXPRESSION OF RELATION BETWEEN ANGLES AND INDICES.

$$\frac{\cos PA}{h} = \frac{\cos PB}{k} = \frac{\cos PC}{l}$$

TO DETERMINE POSITION OF ANY POLE.

Adopting notation of Fig. 188 equations become

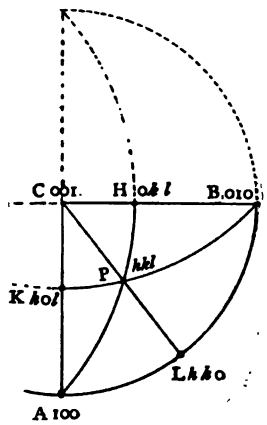


FIG. 188.

$$\cot CP = \frac{l}{\sqrt{h^2 + k^2}}, \tan ACP = \frac{k}{h},$$

$$\tan BAP = \frac{l}{k}; \tan CBP = \frac{h}{l}$$

$$\cos PA = \sin PH = \frac{h}{\sqrt{S}};$$

$$\cos PB = \sin PK = \frac{k}{\sqrt{S}}$$

$$\cos PC = \sin PL = \frac{l}{\sqrt{S}} \text{ in which}$$

$$S = h^2 + k^2 + l^2$$

TO FIND THE ARC JOINING $P = hkl$ and $P' = h'k'l'$

$$\cos PP' = \frac{hh' + kk' + ll'}{\sqrt{SS'}}$$

PROFESSIONAL DRAUGHTSMEN AS SPECIAL STUDENTS IN THE SCHOOL OF ARCHITECTURE.

BY PROFESSOR WILLIAM R. WARE.

It is not the policy of the Faculty of Applied Science to encourage the attendance of special students in the schools under its charge. The catalogue distinctly says that their presence is not desired. Most of the scientific schools in this country, indeed, and some of the colleges, allow men, who are not qualified or who do not wish to follow their full courses, to pursue a partial course according to their choice. But a brief experience in the early days of the School of Mines convinced its managers that the character

of the school was lowered by the presence of men who were incompetent to follow its curriculum, and that its reputation suffered when such men boasted that they had been its pupils. The School of Mines, accordingly, and the Schools of Chemistry and of Engineering that have sprung from it, admit as special students only men who have already graduated in a college or scientific school, extending the privilege to other persons only when they are of mature age, and for reasons of weight.

The School of Architecture has for some years afforded an apparent exception to this rule, having even while a department in the School of Mines obtained leave to try the experiment of admitting professional draughtsmen to the school as special students upon the same footing as college graduates.

Half a dozen years' experience has, on the whole, justified this step. During this period, besides eight or nine college men, about ten times as many practicing draughtsmen have presented themselves, nearly half of whom have been attracted from distant parts of the country, in the west and south. A fair proportion have proved to be men of maturity and character, sufficiently practised in drawing and design to take up our current work, and most of them have possessed sufficient general education to follow with profit the instruction in history and ornament, if not that in mechanics and engineering. Three or four have found time to review their earlier studies and presently to swing into line as regular students, finally taking their degree in due course. Others have remained a longer or shorter time, according as their means held out, some staying in the school only while business was slack, and returning to office work as soon as opportunity offered. Though nominally holding the status of university or post-graduate students, and ranking accordingly with the fourth year men, all whose work is of a post-graduate character, most of them have proved to be hardly up to that mark, and as they were free to take part in whatever was going on that best suited their condition, have taken at first the drawing and design of the second or third year, or both together, advancing to the fourth year work as time went on.

But though the result of the experiment has been sufficiently satisfactory to warrant its continuance, the evils which the School of Mines so much dreaded have not been entirely absent. That men who have been thus temporarily under instruction should,

by the general public, be confounded with the men who have passed our tests and received our diploma, is indeed unavoidable. It is inherent in the situation. It is one of the evils which have to be borne with in view of the advantages from which it cannot be separated. But after all a student who takes only part of our work is really no more dangerous to our reputation than one who stays through only part of the course. The exclusion of special students altogether would still leave us at the mercy of the incompetent and unsuccessful regulars, comprising about two-thirds of all that enter, who fail to complete the course.

The other evil, that of bringing into the school an inferior class of men, though more serious in itself, is more easily dealt with. We soon found that neither a college degree nor three or four years of office practice was any guarantee of maturity of character or of serviceable attainments. A number of the men admitted on the strength of these credentials proved too ignorant or too idle to be profitable company. But such men, even if they cannot be kept out, need not be retained, and the means to this end which we have finally adopted promise to be efficient. Hereafter no draughtsman will be admitted as a special student who is not really proficient in architectural draughtsmanship and no special student will be permitted to stay in the school more than a couple of months who does not fulfil all the requirements exacted of the regular students, in respect of regularity and efficiency, in an eminent degree.

Under these conditions we may well invite professional draughtsmen to come to us and they may well come. At the new site on Morningside Heights, the New York Acropolis, there will be plenty of room for them. Our quarters in Havemeyer Hall will be spacious, clean and quiet, and they will command views out of the windows of some of the most delightful prospects in the world. The special advantages that the school offers such men consist mainly, of course, in freedom in the choice of their studies, in the abundant opportunities offered by the libraries, museums and collections close at hand, and in the facilities which the city presents for the study of work either in progress or completed, whether in architecture, the decorative arts or architectural engineering. But the conditions of attendance are also exceptionally favorable, our special students being received for periods of two months at a time. It is accordingly practicable for an experienced draughtsman who is

for some months out of employment to attend the school for a limited period, taking part in the problems in design that happen to be in hand, and attending such other instruction as he may be qualified to profit by, thus turning bad fortune into good. Most draughtsmen, even the most capable ones, hold their positions by a precarious tenure, and soon discover that in order to be reasonably sure of continuous employment they must improve themselves in knowledge and skill. Intervals of enforced leisure are apt to give such men plenty of time for study and practice, but profitable opportunity is lacking. It is just this opportunity which we have undertaken to supply.

Unlike the young and untrained special students whose presence is so much to be deprecated, such men would enter the school near the top rather than at the bottom, raising rather than lowering the standard of performance. All our work would gain in seriousness and efficiency by their presence, and the regular course itself would become better worth attending.

Until schools are more general in which the elements of architecture can be studied, the offices would seem to be the only source from which we can hope to obtain a supply of students to whom we do not have to teach the A B C of the art. Classes such as those at the Pratt Institute in Brooklyn, the Armour Institute and the Art Institute in Chicago and others, in St. Louis, Cincinnati and elsewhere, and the evening schools maintained in many places throughout the winter, do indeed furnish a certain number of men capable of entering in advanced standing. The competitions carried on by the Society of Beaux-Arts Architects also, in which draughtsmen all over the country are invited to take part, and which, perhaps, are not as well known nor as much frequented as they should be, and the admirable *ateliers* maintained by some members of this society in New York, go further in the same direction. They all point to a time when such schools of architecture as our own can exact some proficiency in the elements of the art as a condition for admission.

In thus opening our doors to men who are already somewhat proficient in design, we are greatly extending and expanding the service of the School to the community and to the profession, and doing it with the least possible trouble and expense. A considerable part of the pains spent upon our regular students is of course pretty much thrown away. Out of thirty or forty new

men who every year pass our entrance examinations, not more than ten or fifteen complete the four years' course. The rest drop by the way, and the time and labor bestowed upon them, and money too, for every man costs twice as much as he returns in tuition fees, is largely wasted in proving, to themselves and to us, that they made a mistake in coming to us at all. Even those who remain are apt not to take their work any too seriously. It is indeed more difficult for schools of art, and even for schools of science, to maintain the dignity and maturity of character that should mark professional study, than it is for schools of law and medicine to do so. For obvious reasons they tend to rank rather with the undergraduate courses in the colleges. Many of our students are boys fresh from school who have, as has been said, no real vocation for the work, and who take it merely as the alternative to a college career. They are indeed rather disposed to assume the title of Freshmen and Sophomores, and with it the manners and customs these names suggest. The cure for this will, it is to be hoped, be found in the new policy lately adopted by the academic department of the University. Students in Columbia College will hereafter, during their four years' course, be permitted to take as electives all the studies comprised in the first two years of the School of Architecture. They will then be able to complete their professional studies in two more years instead of in four. This six-year programme will meet the case of boys who are ready and glad to continue their general education, though they may be unable or unwilling to undertake eight years more of schooling, while it will furnish them to us as men fresh from college instead of boys just out of school. Meanwhile, we are, as has been said, encouraging the attendance of older and more serious men by offering special inducements to draughtsmen of experience, who have already passed their probation, and vindicated in the open market their claim to a place in the profession. Such men belong to just that class of mature, serious, eager and receptive students, in whose service it is worth while to spend time, pains and money. Such have not been lacking among the special students of these five or six years. As was said of one of the first of them who presented himself, "Give them a little push, and they will run for two days." The more serious and capable men in our regular course, and such are by no means rare, would be the first to profit by and to welcome the more vigorous temper which such an element could hardly fail to infuse into our society.

But whatever prowess these men may evince and whatever service we may do them, or they us, it is in the regular students, the men who fulfill all the requirements of our course and who in sign that they have done so receive our diploma, that our main interest lies. Whether this consummation comes at the end of four years of strict adherence to our curriculum or by more disconnected studies, is a matter of detail. It is the end that is the important thing, no matter how it is reached. This is the end for which the School was established. The main function of the School is to furnish to the country a body of generously educated architects, gentlemen and scholars, who shall in intellectual character and professional culture help to set the profession where a similarly broad education has placed the professions of law and medicine. There are lawyers and doctors, useful and eminent, who have not this mark. But that is not the kind who receive their education at a university. There are still architects of eminence who, as in middle ages, are master builders. To such and to others whose training lies all on one side we are glad to do all the service that we can, by the way. But we do not forget that the regular course is our main work and it is the hope of finding among these irregulars able recruits for our main army that adds zeal to our efforts in their behalf. The statutes of the University provide that any special student may obtain a degree by passing all the required examinations and enrolling himself as a regular student at any time up to the beginning of the fourth year. It is to be hoped that as the special students in architecture increase in number and improve in quality, an increasing proportion of them may avail themselves of this provision.

The maintenance side by side of two classes of students, doing substantially the same work, though standing upon so different a footing, might be expected perhaps to present some inconveniences, especially at first, before relations were adjusted. Each class might naturally regard the other as enjoying exclusive privileges. Some delicate questions of fees and of promotion have already arisen, and are in course of what it is hoped may prove satisfactory adjustment. But it does not appear that the colleges where similar conditions obtain have experienced any serious embarrassment on this account. The regular and special students seem to live comfortably together without antipathies or antagonisms.

It is more significant to observe that this condition of things

may tend toward the practical solution of a question which as a matter of theory might be interminably debated, as indeed it has been, and still is. It may well be held that in the study of any profession there is a definite series of topics which had best be taken up in a certain definite order, that the student has no means of forming a sound judgment as to what these topics are, or what should be their proper sequence, and that accordingly the sensible course for a school of architecture, as for a law school or a medical school, is to prescribe the path to be trod, making it neither too long nor too broad, and to require a strict adherence to it. This means a curriculum, and it can reasonably be contended that however an elective system, with freedom of choice in the selection and the arrangement of studies, may be suited to the wide field of liberal culture, it has no place in the road to technical attainment, in which every step is necessary to the one that is to follow it.

On the other hand it may be said that architecture, at least, presents so many sides, each requiring a special capacity in order really to approach it to advantage, that a comprehensive curriculum can give only a superficial training, and that men should be allowed and encouraged to devote themselves somewhat exclusively to whatever they are best fitted for. Grown up men at any rate, who have found out by experience what they can do to most advantage, should have a free opportunity to pursue the studies they feel they need and to take them up as they may be ready for them. This would permit them to attack one subject at a time and to concentrate effort upon it, studying as men study, with continuity of interest, not in broken snatches of time, like children.

This contention is backed by the great example of the *École des Beaux-Arts*, in which the principle of freedom of choice, of what is sometimes called that of the European University as opposed to that of the American College, finds a splendid exemplification.

Which procedure is best adapted to the needs of architectural education in this country only experiment can show, and it is this experiment that we are in a somewhat favorable position for trying. Our regular course offers the first alternative to men who are especially fitted for it by their preparatory studies, giving them three years of training in history and design and in scientific and practical construction, followed by a year given exclusively either to architectural design, or to architectural engineering, as each student may elect. Special students follow the other alternative, and

as it is open only to men specially qualified for it by experience, it may, if happily administered, prove equally advantageous. It is to be expected that here as elsewhere the two will develop harmoniously side by side, each meeting the needs of its own men better than the other could do. But it may happen that one or the other may prove so much more congenial to the temper of the time that it shall engross pretty much all our activities. In that case the school would present the aspect either of a strictly ordered community, with a few outsiders feeding on the crumbs from the table of the regular household, as at present, or possibly as a school where most men study what they choose, as they choose, with an auxiliary or perhaps in that case a preliminary course, like our present first year, for those who need or desire a preparatory discipline.

But these are the issues of the future, to be determined by the concurrence of natural forces. It is not for us to prejudge the event, under the influence of prejudices derived from the observation of what has succeeded or failed, here or abroad, but to give both experiments a fair trial, as we are happily in a position to do.

ABSTRACTS.

ANALYTICAL CHEMISTRY.

By Elwyn Waller, Ph.D.

Volatility of Salts.—Norton and Roth (J. Am. Chem. Soc., XIX., 155). Bunsen's mode of testing was applied, which consists in noting the comparative length of time required to volatilize 0.01 gm. of the substance from the loop of a platinum wire held in the hottest part of a Bunsen flame. The disappearance of color is very decidedly marked. The results were:

NaCl	13.	seconds.	KBr	7.	seconds.
Na_2SO_4	130.	"	KI	5.5	"
Li_2CO_3	130.	"	$Na_2B_4O_7$	215.5	"
K_2SO_4	87.5	"	NaF	104.5	"
Na_2CO_3	95.5	"	KF	39.5	"
K_2CO_3	47.	"	$BaCl_2$	1560.0	"
KCl	12.	"			

Recovering Platinum from Waste Solutions.—Wiley (J. Am. Chem. Soc., XIX., 258). Al turnings in conjunction with HCl have been used with great success. After all Pt has been precipitated and all Al dissolved, the Pt black must be digested for a time with HNO_3 to remove the Cu which is usually present in commercial Al.

Sodium Peroxide as a Third Group Reagent.—Parr. (J. Am. Chem. Soc., XIX., 341). When added in excess the effects are:

Al and Zn redissolved as aluminate and zincate. Fe precipitates as dense red brown precipitate, almost insoluble in HNO_3, carrying *no* P_2O_5 with it. Mn separates as $MnO_2 \times H_2O$, Co in similar manner as $Co_2O_3 \times H_2O$. Ni as $Ni(OH)_2$. Boiling this precipitate with Br water converts it to $Ni_2O_3 \times H_2O$, which when suspended in water alone decomposes KI (without addition of acid), constituting a delicate test for Ni. A scheme for the management of the group is given.

Alkametric Solutions.—Sodium oxalate for standardizing—Sörenson (Chem. Ztg. Rep., 1896, 235). Dissolve the commercial article in water, render slightly alkaline with NaOH, evaporate and crystallize out. Recrystallize and dry at 125° to 150°. The salt is anhydrous and not hygroscopic. For use, weigh out, ignite gently to Na_2CO_3 and dissolve. It is also superior to $H_2C_2O_4$ for standardizing permanganate.

Standard Oxalic Acid Solutions.—Preservation. Fricke (Chem. Ztg., 1897, No. 26). The addition of 1 gm. H_3BO_3 per litre served to preserve dilute solutions of $H_2C_2O_4$. The preservative is without action on $K_2Mn_2O_8$.

Acidimetric Standardization.—Worms. (J. Soc. Phys. Chim., Rus., XXVIII., 432). A decime solution of HCl, the strength of which was determined by weighing the AgCl precipitated by it, was tested with the following results per 100 cc.:

I. By Weight of AgCl		0.365 gm. HCl.
II. By Na_2CO_3 from $NaHCO_3$	calcined	0.358 "
	dried at 150°	0.362 "
III. By oxalic acid	Two preparations.	0.369 "
		0.367 "
IV. By borax	Two preparations.	0.365 "
		0.367 "
V. Evaporation to dryness with NH_4OH and weighing		0.364 "

All the salts used were purified by repeated recrystallizations. Methyl orange was used with the Na_2CO_3 and borax, phenol phthalein with the oxalic acid. Oxalic acid recrystallized from a solution containing 2 per cent. HCl was found to be the best.

Preference is given to borax as a material for standardizing.

Caustic Alkali in Presence of Carbonates.—Lunge (Zts. Augew. Chem., 1897, 41). A comparison of three methods was made, *a* by gas volumetric method, *b* by direct differential titration, using phenolphthalein and methyl orange indicators, and *c* by Winkler's method. Titration of one portion with methyl orange indicator and in another portion adding $BaCl_2$ and then titrating with phenol phthalein indicator, using the precaution to add the N/5 HCl for back titration very gradually. When only small proportions of carbonate were present, all three methods gave identical results. When more of the alkali was present as carbonate than as caustic, method *b* proved incorrect, while the others proved correct.

Alkalimetric Carbonates in Lyes and Alkaline Carbonates.—Kuster (Zts. Anorg. Chem., XIII., 127). An elaborate investigation of different methods. The conclusions are: 1. In mixed caustic and carbonate solutions, Winkler's method with $BaCl_2$ (phenol phthalein indicator) is the only correct one. Total alkali can be determined with methyl orange indicator.

2. Methyl orange is colored by CO_2. In using it for titrating carbonates one should titrate to a "normal color" obtained by saturating a water solution of the color with CO_2.

3. Phenol phthalein shows color in dilute bicarbonate solutions. The color is weakened by the presence of Na salts of stronger acids, and is destroyed by considerable excess of CO_2. It is unsuited for the accurate titration of solutions containing carbonates.

4. Many of the phenomena noted are in accord with Arrhenius' views of the ion decomposition of salts.

Potassium Estimation.—Warren (Chem. News, LXXV., 256). After precipitating from the chloride solution by $PtCl_4$ the aqueous mixture is evaporated low, and then double its volume of a mixture of equal parts of amyl alcohol and ether are added. This renders the precipitate very dense; after washing a few times with this mixture the precipitate is treated with 5cc. $HCHO_2$ and heated to boiling. When the solution has become brown a slight excess of ammonia is added. On boiling again Pt separates in dense flocks which can be readily filtered, etc.

Potassium Determination.—Prager (Chem. Ztg., XX., 269). Correct results can be obtained by Fresenius' short method, if slow evaporation is

effected in an atmosphere free from ammonia, the weighed filter well washed with alcohol and hot water previous to weighing for reception of the precipitate, and the drying is effected at 110°. Ruer (*ibid.*, p. 270) asserts that the determinations made in accordance with the directions of the Stassfurth syndicate are all about 0.5 per cent. too high. They prescribe drying the K_2PtCl_6 for 20 minutes at 130° and multiplying its weight by 0.3056 to get KCl. He finds that this factor is only correct after drying the precipitate at 130° for 12 hours. Drying for half an hour and using the factor 0.304 gives correct results. Bauer (*ib.*, p. 270) prefers dissolving the precipitate through the filter (by use of hot water) into a weighed capsule, evaporating, drying at 120° and weighing, thereby avoiding double weighing of the filter, possibility of reduction of the precipitate, freeing reduced Pt, etc.

Calcium Carbonate and Sulphate in White Paint.—Thompson (J. Soc. C. I., XV., 791). A mixture of $CaCO_3$ and $PbSO_4$ when treated with water react upon one another, producing $CaSO_4$ and $PbCO_3$ It was found possible to determine Ca present as $CaCO_3$ in a white paint, by treating 1 gm. of the (dry) pigment in the cold with with a mixture of 9 parts of 95 cent. alcohol with one part of conc. HNO_3 (Gr. 1.4). The material is digested 20 minutes with some of this mixture, and the clear solution decanted off through a filter. This operation is performed four times. The material is then filtered and washed with the mixture, and the solution evaporated to dryness, adding a little sulphuric acid to destroy $H_2C_2O_4$, which may form by the reaction of HNO_3 on alcohol. Cool, take up with water, add NH_4OH and $HC_2H_3O_2$, pass H_2S to remove Pb and Zn, and determine CaO in the filtrate by use of oxalate. The CaO thus found is that present as $CaCO_3$. Deducting from total CaO we obtain that present as $CaSO_4$.

Separation of Barium, Strontium and Calcium.—Rawson (J. S. C. I., XVI., 113). $Ba(NO_3)_2$ and $Sr(NO_3)_2$ are both insoluble in concentrated HNO_3, while $Ca(NO_3)_2$ is soluble. The carbonates are dissolved in HNO_3 evaporated to dryness on the water bath, cone HNO_3 (Gr. 1.44 or higher) is added and the mixture well stirred. After filtration the residual nitrates are dissolved in water, and Ba separated as chromate, the usual necessary conditions being obtained.

Alumina and Ferric Oxide in Phosphates.—Thompson (J. Soc. C. I., XV., 868). The acetate process affords erroneous results because the $NH_4C_2H_3O_2$ causes a decomposition of the acid calcium phosphates, a portion of the CaO as phosphate accompanying the precipitate (of $Al_2(PO_4)_2$ and $Fe_2(PO_4)_2$). If, however, the cold HCl solution of a mineral phosphate is carefully neutralized with NH_4OH, until it is neutral or faintly acid to lacmoid paper, the whole of the $Al_2(PO_4)_2$ and $Fe_2(PO_4)_2$ will precipitate free from Ca salt.

Washing the precipitate with dilute $NH_4C_2H_3O_2$ solution decomposes the precipitate, rendering it basic. Washing with a 1 per cent. solution of NH_4NO_3 containing 0.2 per cent. $NH_4H_2PO_4$ per litre avoids this difficulty.

Basic Acetate Precipitations (*Ferric*).—Brearley (Chem. News, LXXV., 253). Some experiments are recorded which have been made with a view to determine within what limits the amount of alkaline

acetate may be advantageously confined. In neutralizing closely, some $Fe_2(OH)_6$ is formed, which dissolves in the Fe_2Cl_6 remaining, and only so much acetate is required as will suffice to react with the Fe remaining as chloride and release the $Fe_2(OH)_6$.

Hydrogen Peroxide in Titrating Iron.—Ross (Chem. News, LXXV., 81). After reducing a ferric solution, an excess of $K_2Cr_2O_7$ may be added, and the excess of the latter determined by shaking up in a closed flask connected with an eudiometer in which the volume of O evolved may be read off. All of the O is not set free until about five minutes have elapsed. The reactions are given as:

$$K_2Cr_2O_7+H_2O_2+H_2SO_4=K_2SO_4+2H_2O+Cr_2O_7$$
$$Cr_2O_7+3H_2SO_4+4H_2O_2=Cr_2(SO_4)_3+7H_2O+O_3.$$

Phosphides of Chromium and Manganese.—Granger (Abstr. Chem. News, LXXV., 95). The substance in fine powder is fused with KOH, the temperature being gradually raised to dull redness, and there maintained for 1½ hours. After cooling, the mass is dissolved in boiling water. For the Cr compound, acidify with HNO_3, precipitate by molybdate, and in the filtrate, reduce to Cr_2O_3, and precipitate twice to purify the Cr_2O_3.

For the Mn compound, acidify with HCl, neutralize with NH_4OH, and add $(NH_4)_2S$. Evaporate to dryness, add more $(NH_4)_2S$, and water, filter off MnS, etc. The precipitate may serve for determination of Mn, the filtrate for P_2O_5.

Titanic Acid.—Morgan (C. N., LXXV., 134). The methods described by Blair, and by Arnold, in their respective books on steel analysis, etc., are combined. The TiO_2 is precipitated by $(NH_4)_2HPO_4$, an excess of the precipitant being kept in the solution when filtering. The preciptate is dissolved in HCl, the solution evaporated to hard dryness (baked). After treating with HCl, the insoluble residue is filtered off and fused with ten times its weight of K_2CO_3(Na_2CO_3?). After extracting with a little water, the insoluble portion is fused with $KHSO_4$, dissolved in 10 cc. HCl and 50 cc. SO_2 solution, and pure TiO_2 precipitated by adding 20 gms. $NaC_2H_3O_2$, one-sixth the volume of $HC_2H_3O_2$, and boiling for a few minutes.

Volumetric for Nickel.—Examination of Methods. Goutal (Ann. de Chim. Analyt. I., 305). The conclusions are: 1. The Br and KCy method indicated by Mohr and recommended by Carnot is simple and accurate when sensible quantities of Ni are present. 2. Moore's KCy titration is especially useful in cases of low percentages of Ni. Good results are obtained if the $AgNO_3$ in the solution is varied inversely in proportion to the amounts of Ni in the substance. Co, Mn, Cu, Zn and Fe should not be present. The conditions necessary are a slightly alkaline solution, not too much NH_4 salts, and a temperature not over 20° C. 3. The phosphate, molybdate and nitroso-naphthol methods are more difficult and slower, but are accurate in experienced hands. 4. Other methods are less accurate and apparently not superior to gravimetric methods.

Separating Nickel from Cobalt, Iron, etc.—Pinerua (Chem. News, LXXV., 193). The method is based on the insolubility of $NiCl_2$ in

ether when saturated with HCl at a low temperature. The hydrated chlorides (0.3 to 0.4 gm.) are dissolved in the smallest possible quantity of water, and 10 to 12 cc. of fuming HCl added, then 10 cc. of ordinary ether. The mixture is well shaken, and anhydrous HCl passed into saturation, the tube in which the mixture is contained being surrounded by melting ice. Ni separates as yellow $NiCl_2$, $CoCl_2$ remaining in solution (blue); if Fe is present the solution will be green. The precipitate is washed by decantation with ether saturated with HCl, then washed on the filter with the same. It may then be dissolved in water and estimated by well known methods. For the complete separation from Fe the operation must be repeated several times. $AlCl_3$ is also insoluble in ether saturated with HCl, and the method may be used to separate Al from Co in the same manner.

Nickel and Zinc as Phosphates.—Clark (J. Soc. C. I., XV., 866). Dirvell's method of determining Co. by precipitating as $CoNH_4PO_4$ in NH_4OH solution is effective, provided the Co is all in the cobaltous state. To separate Ni in presence of Co add to a solution containing both as chlorides, 10 times as much $(NH_4)_2HPO_4$ as will suffice to combine with them, heat with HCl and an excess of Br. Supersaturate with NH_4OH, add a little H_2O_2 to insure oxidation of Co, cool, render just neutral with HCl, add 20 cc. of alcohol and allow to stand, pale green $NiNH_4PO_4$ separates. Wash with dilute alcohol, ignite and weigh $Ni_2P_2O_7$.

$ZnNH_4PO_4$ can be brought down quickly and completely by neutralizing exactly in the same manner.

Determining Zinc as ZnS.—Aston and Newton (C. N., LXXV., 133). Mixing ZnO with S and igniting in a current of H gas is a method mentioned by Fresenius. The authors find that ZnO from the nitrate treated in this way affords much less than the theoretical amount of product, at best about 96 per cent. after repeated treatments. ZnO from ZnS, $ZnCO_3$ or $ZnSO_4$ gave theoretical results.

Volumetric for Zinc.—Dementief (J. Soc. Phys. Chem. Russ., XXVIII., 222). Add to the solution of Zn an excess of NaOH, sufficient to redissolve the $Zn(OH)_2$. Then divide the solution exactly in halves. In one half titrate with standard acid and tropæolin OO indicator. This gives both $Zn(OH)_2$ and NaOH. In the other half titrate with standard acid and phenol phthalein, which gives only the NaOH. The difference is the measure of the $Zn(OH)_2$ present.

Zinc Dust.—Wahl (J. Soc. Ch. Ind., XVI., 15). A weighed quantity of the dust is suspended in a little cold water in a flask and $Fe_2(SO_4)_3$ added (no free acid). In a short time the reaction occurs with evolution of heat, after which acidification with H_2SO_4 and titration will serve to complete the test. In the discussion it was stated that the method was not new, and in case the Zn dust were adulterated with iron filings it was utterly fallacious.

Separating Tungsten from Titanium.—Defacqz (C. Rend., CXXIII., 823). Ignite at dull red heat with 8 parts KNO_3 and 2 parts K_2CO_3 for 20 to 30 minutes. Leach out with water, finally wash on a filter with NH_4NO_3 solution. W is estimated in the filtrate by $Hg(NO_3)_2$, while the residue (containing Ti) is fused with $KHSO_4$ and managed as usual.

Separation of Silicic and Tungstic Acids.—De Beuneville (J. Am. Chem. Soc., XIX., 377). Treatment with ammonia even after ignition will dissolve some SiO_2. Volatilizing the SiO_2 by use of HF and H_2SO_4, as recommended by Professor Arnold, is the best method. The results of a number of experiments are given to illustrate the point.

Commercial Thorium Nitrate.—Fresenius and Hinz (Fres. Zts. Anal. Chem., XXXV., 525). 20 gms. were dissolved in water. After dilution to 3 litres, the solution was precipitated hot with $Na_2S_2O_3$. The precipitate was dissolved in HCl. The residue was ignited, fused with $KHSO_4$, dissolved in dilute HCl and precipitated with ammonia. This precipitate was dissolved in HCl and added to the main solution, which after large dilution was again precipitated with $Na_2S_2O_3$. The filtrates from both operations were precipitated by ammonia, washed, dissolved in HCl and evaporated. The residue was taken up with water, and a few drops of HCl, and precipitated twice with $Na_2S_2O_3$. The combined filtrates were precipitated by ammonia, dissolved in HNO_3. After repeating this process the ammonia precipitate was dissolved in HNO_3 evaporated to dryness, and the portion soluble in water precipitated by $H_2C_2O_4$. The precipitate contained Ce, Yt and Nd(La). Fused with $KHSO_4$ precipitated with ammonia, dissolved in HCl nearly neutralized with Na_2CO_3, added $NaC_2H_3O_2$ and $HC_2H_3O_2$, then NaClO and boiled, dissolved the precipitate in HCl and repeated, then dissolved in HCl precipitated by ammonia weighed CeO_2.

The filtrates (containing Yt, Nd and La) were acidified with HCl, boiled, and precipitated with ammonia, and this dissolved in HCl. After evaporating to dryness it was taken up with a few drops of water, and a saturated solution of K_2SO_4 added. After long standing, the Nd and La compounds were filtered off, washed with K_2SO_4 solution, and in the filtrate Yt precipitated twice by ammonia, ignited and weighed.

The K_2SO_4 precipitate was dissolved in HCl, precipitated with ammonia, redissolved, and precipitated by $H_2C_2O_4$, washed, ignited and weighed.

Separating Thoria from Zirconia.—Delafontaine (Chem. News, LXXV., 230). Fusing the material (ore or oxides) with twice its weight of KHF_2 affords K_2ZrF_6 soluble in boiling water containing a little (few drops) of HF. The insoluble portion decomposed by H_2SO_4 and ignited at below red heat gives the Ce Th, etc., as sulphates, which can be separated by the oxalate treatment.

Molybdic Acid by Iodometric Method.—Gooch and Fairbanks (Zts. Anorg. Chem., XIII., 101). In an HCl solution addition of KI and heating gives the reaction:

$$2MoO_3+4HI=2MoO_2I+I_2+2H_2O$$

Distilling over the I and titrating the same with standard $Na_2S_2O_3$, can be made to give correct indications, if for 0.2 to 0.4 gm. MoO_3, the original volume of 40 cc. is boiled down to 25 cc. in an atmosphere of CO_2, not over 0.5 gm. excess of KI is used. In the cold the MoO_3 re-oxidizes in contact with I solution. It was found that this re-oxidation could be measured, and the work conducted in a flask only partially closed by placing a $CaCl_2$ tube in the throat. The charge should be:

MoO_3 0.1 to 0.3 gm., KI 0.5 gm. H_2O .20 cc., HCl (conc.) 20 cc. This is boiled down to 25 cc., then diluted, about 1 gm. $H_2C_4H_4O_6$ added, and then an excess of normal I solution. The solution is then placed in a flask provided with a stopcock funnel, and connected with a Will-Varentrapp bulb containing KI solution. Through the stopcock funnel is added a little NaOH, the neutralization is finished with $NaHCO_3$, and after standing for an hour or two, the excess of I remaining may be titrated.

This method can be applied to the "yellow precipitate," obtained in phosphoric acid determinations ($24MoO_3P_2O_5.3(NH_4)_2O,2H_2O$). (ib p. 117.)

Selenium-Gravimetric Determination.—A. W. Pierce (Zts. Anorg. Chem. XII., 409). In a solution containing selenates, acidifying with HCl, adding KI and boiling 10 minutes separated all the Se in the elemental form. This was filtered on a weighed filter of asbestos, dried at 100° and weighed. With small amounts of Se correct results were obtained, with over 0.2 gm. of Se; the gravimetric determination showed too high, whereas the determination of the I liberated showed too low results. KI was evidently held by the precipitate. When, however, the solution was diluted to 400 cc. before acidifying with HCl, 3 gms. KI added, and the solution boiled for 10 to 20 minutes, correct results were obtained when over 0.4 gm. Se was present.

Monazite Sand.—Analytical experiments. Glaser (J. Am. Chem. Soc. XVIII.). Fusion with alkaline carbonates as recommended by Wohler failed to render the TiO_2 extractable by water. P_2O_5, Al_2O_3 and much of the SiO_2 could be extracted by this means. The portion insoluble in water could be rendered soluble by digestion with conc. H_2SO_4 or fusion with $KHSO_4$. Addition of Na_2SO_3, boiling for some time, and passing H_2S first through the hot, and then through the cold solution, was effective in separating TiO_2.

In separating Th and metals of the Ce group by $(NH_4)_2C_2O_4$ the solution must not be too acid. Also, a considerable excess of the reagent should be used to keep Zr in solution. $Th(C_2O_4)_2$ separates on cooling, but this property is not effective in separating Th from the Ce group. Boiling the sulphates after addition of $Na_2S_2O_3$ also gave an incomplete separation, though the ThO_2 thus obtained was quite pure.

Separation of Ce by fractional precipitation with weak ammonia was also ineffective.

A portion of a Welsbach mantle was examined by boiling with H_2SO_4 and fusing the portion remaining with $KHSO_4$. The solutions thus obtained were treated separately by the same method, nearly neutralizing with ammonia, adding hot solution of $(NH_4)_2C_2O_4$ to the boiling solution, cooling and filtering. The precipitates consisting of $Th(C_2O_4)_2$ were ignited and weighed. In the filtrates $Zr(O_2H)_4$ was precipitated out with ammonia, redissolved in HCl and reprecipitated. The action of the H_2SO_4 appeared to have effected a partial separation.

A solution containing $Th(SO_4)_2$ and sulphates of the cerium metals, when treated boiling hot with $(NH_4)_2C_2O_4$ and $NH_4C_2H_3O_2$, gave a precipitate containing no Th, and in the filtrate the Th was separable by use of NaOH. It is noted that when acetate has been used, the $Th(C_2O_4)_2$ obtained, when dissolved in a mineral acid, cannot again be precipitated completely by $(NH_4)_2C_2O_4$.

The pl. n of analysis in scheme form is as follows:

Determine TiO_2 and SiO_2 on a separate portion.

Pulverize finely, dissolve by prolonged heating with conc. H_2SO_4 (or fusion with $KHSO_4$). Evaporate down to remove SiO_2, pour slowly into ice cold water.

Res. A. SiO_2, Ta, traces of Ti, Th and Zr. Remove SiO_2 by HF and H_2SO_4.

Res. Ta.

Sol. add to Sol. A.

Sol. A. Pass H_2S first when boiling, afterward cold.

Allow to settle and then filter.

Ppt. B = TiO_2 ± Cu, etc., and members of Gr. V.

Sol. B. Boil out H_2S, nearly neutralize with NH_4OH. To the boiling solution add *excess* of $(NH_4)_3C_2O_4$ (hot solution 100 cc. for every 2 gms. of mineral). Cool over night.

Ppt. C. Th and Ce metals. Ignite to oxides, convert to sulphates, nearly neutralize with NH_4OH. Boil and add excess of $(NH_4)_2C_2O_4$, after a time (before cooling) add a few cc. of $NH_4C_2H_3O_2$. Cool over night, filter.

Sol. C. Add NH_4OH.

Ppt. E. Dry, ignite, fuse with $NaKCO_3$, dissolve in hot water, filter.

Sol. E. Al_2O_3, P_2O_5.

Sol. F. add to Sol. E.

Res. F. Dissolve in H_2SO_4, add NH_4OH.

Ppt. D. Ce metals. Dissolve, precipitate by NaOH, while precipitate is fresh, pass Cl gas to separate Ce from La and Di.

Sol. D. Th, Precipitate by excess of NH_4OH

Ppt. G. Dissolve in dilute HCl. Nearly neutralize with NH_4OH. Pour slowly into *Sol* G. for CuO. a mixture of $(NH_4)_2CO_3$ and $(NH_4)_2S$ solutions.

Ppt. H. Fe, Mn, Al.

Sol. H. Zr, Yt, Be. Acidify with HCl, boil out CO_2, cool, add excess of NaOH.

Ppt. I. Zr and Yt Dissolve in HCl, warm, add Na_2SO_4, cool. When cold Zr separates. From solution precipitate Yt by NH_4OH. Redissolve and reprecipitate to purify.

Sol. I = Be

Electrolytic Determination of Cadmium.—Avery and Dales (J. Am. Chem. Soc., XIX., 379). Excellent results were obtained by using a formate solution. Not over 0.1 gm. of the metal should be present in 150 cc. of the solution. This amount of metal should be deposited on not less than 100 sq. cm. of surface. Voltage should not exceed 3.4 and amperage 0.15 to 0.20. If these conditions are rigidly maintained the results are better than by any other method tried.

Lead in ores.—Meade (J. Am. Chem. Soc., XIX., 374). Weigh 1 gm. (more if poor) of the ore in a Pt dish covered with a watch glass.

Add 40 to 50 cc. of a mixture of conc. H_2SO_4 and HNO_3 (1:3). Heat until all action has ceased. Remove the cover, rinse it off, add 10 to 15 cc. HF and evaporate until dense fumes of SO_3 come off; cool, dilute to about 100 cc., digest until all soluble salts are in solution, filter and wash first with 2 per cent H_2SO_4, then with alcohol. Dry, ignite and weigh, using the usual precautions. Ba, Sr and Ca may cause erroneous results.

Mercury in Ammonio-Mercuric Chloride.—Thompson (Chem. and Drugt. L., 234). Estimation of the Hg in metallic form gave low results from loss of Hg in drying. Excellent results were obtained by dissolving in HCl and adding acidified solution of potassium hypophosphite ($K H_2PO_2$), Hg_2Cl_2 is almost immediately precipitated. After standing 12 hours the precipitate is filtered off, dried at 100° and weighed.

Gold and Silver in Ores.—Truchot (Ann. Chem Anal., App. I., 365). Roast 100 to 200 gms. of the pulverized ore, and then digest 30 hours with Br water. In the filtrate separate Au by $FeSO_4$, and extract Ag-Br from the residue by hot conc. NH_4Cl.

Arsenic-Volumetric method.—Szarvasy (Berichte, XXIX., 2,900). As_2S_3 or As_2S_5 after precipitation is filtered through an asbestos plug in a piece of combustion tubing. After washing with water, alcohol and ether, the contents of the tube is thoroughly dried in a current of CO_2. Then a plug of glass-wool is forced in to within about 5 cm. of the precipitate. A current of O is then passed through the tube and a spot about midway between the plugs is heated to dull redness. Maintaining the heat at that point, the precipitate is gently and gradually heated with another flame so as to oxidize the precipitate. As_2O_3 deposits on the walls of the tube beyond the first flame, the small amounts which would otherwise escape being caught by the glass-wool plug. If the sublimate has the least tinge of yellow the operation has been too much hastened and some sulphide has escaped exidization. In that case one may temporarily reverse the current of O and drive the whole back to be oxidized over again. When the oxidization is terminated, drive out the SO_2 remaining with a current of air, dissolve the As_2O_3 through the asbestos plug by use of NaOH solution, rinse out, acidify with HCl, add $NaHCO_3$, and titrate iodmetrically. With orpiment, realgar, etc., the S may be simultaneously determined by passing the SO_2 formed during the oxidation into Br solution and manipulating by well known methods.

Platinum sulphide.—Antony and Luechesi (Gazz. Chim. Ital. XXVI., 218), H_2S reacting with H_2PtCl_6 solution when heated to 90° precipitates all the Pt as sulphide. At ordinary temperatures the precipitation is not complete. A precipitate of variable composition containing probably $Pt(HS)_4$ separates, and a colloidal sulphide also forms.

At ordinary temperatures in very dilute solutions a sulphide entirely colloidal is formed.

Formaldehyd as a reagent with oxidized Halogens.—Grützner (Arch. Pharm. CCXXXIV., 634). Adding $AgNO_3$ and formaldehyd to a solution of $KClO_3$ and then acidifying with HNO_3 gives the reaction; $HClO_3+3CH_2O+AgNO_3=3CH_2O_2+AgCl+HNO_3$.

The action is hastened by warming.

$HBrO_3$ reacts in a corresponding manner, but requires long heating. HIO_3 is not reduced. $HClO_4$ and HIO_4 are but slightly affected.

Separating Chlorine and Bromine.—Baubigny and Rivals (C. Rend. CXXIV., No. 16). The action of $K_2Mn_2O_8$ on iodides (conversion to iodate in neutral or alkaline solution) is utilized in analytical work. Bromides or chlorides are unaffected. If, however, $CuSO_4$ solution is added to a solution of mixed bromide and chloride containing $K_2Mn_2O_8$ a similar action occurs with the Br, and in the remaining liquid (after standing) the Cl can be estimated alone by $AgNO_3$.

Analysis of Iodides.—Gooch and Walker (Am. J. Sci. [4] III., No. 16) addition of HIO_3 (or alkaline iodate and H_2SO_4) gives the reaction: $HIO_3+5HI=6I+3H_2O$, in which one-sixth of the I set free (estimated by $Na_2S_2O_3$, etc.) is due to iodide. The method works well when bromides or chlorides are not present. When these *are* present they react with the HIO_3 in a similar manner to that above and give high results.

Properties of some Metallic Sulphates.—Caven and Hill (J. Soc. Ch. Ind., XVI., 29). $AlPO_4$, like $FePO_4$, is slowly hydrolyzed by water. It is soluble in solutions of Al salts, to some extent even at the boiling temperature. Its solution in alkaline hydrates is partially reprecipitated by addition of NH_4Cl. The compound is soluble in $HC_2H_3O_2$ in the cold, and reprecipitated by boiling, but is not precipitated by $NH_4C_2H_3O_2$ in the cold. The properties of $CrPO_4$ are almost precisely the same. $Cu_3(PO_4)_2$ was found also to be hydrolyzed by water. The phenomenon is accompanied with a change of color in the precipitate, from sky blue to light grass green. The compound is completely hydrolyzed by KOH solution. $BiPO_4$, like the former, was found to be soluble in solutions of salts of the metal. It was partially hydrolyzed by KOH, but not at all by water. $Pb_3(PO_4)_2$ is not soluble in excess of Pb salts. As to hydrolyzation, it appeared similar to Bi.

Phosphorus by Iodometric Method.—Fairbanks, see "Molybdic acid by iodometric method."

Insoluble Phosphorus in Iron-ores.—Mixer and Dubois (Am. Inst. Min. Eng., Chicago meeting, Feb., 1897). Some iron ores contain phosphates not extracted by treatment with acid. Calcining with limited amount of Na_2CO_3, or of MgO, were successful in rendering this soluble, but rendered the determination slow. The most rapid method found also to be accurate consisted in calcining without addition. Treat about 1.5 gms. of the ore with 25 cc. HCl (Gr. 1.1). Evaporate to a syrup. Dilute and filter. Burn the filter in a crucible, break up and ignite at red heat for 2 minutes, add water and acid, boil 5 minutes and then filter off.

Soluble Phosphates in Fertilizers.—Stock (J. S. C. I., XVI., 107). 20 to 30 gms. of the well mixed fertilizer are put into a strong bottle, and 2 to 3 litres of water added; after thorough shaking, several glass marbles are put in, and after stoppering the bottle is swung to and fro in a horizontal position for 2 or 3 hours. After settling an aliquot portion of the solution is taken for analysis.

Phosphates in Water.—Lepierre (Bull. Soc. Chim., XVI., 1213). The Brussels congress fixed the limit at 0.0005 gm. P_2O_5 per litre. Determinations by weighing the yellow precipitate as usually recommended are erroneous, the yellow precipitate being soluble to the extent of 0.02 to 0 06 gm. per 100 cc. A colorimetric method is recommended. The standards are made by dissolving 0.075 gm. of $NH_4,Na,H,PO_4.4H_2O$ in one litre (equivalent practically to 0.025 gm. P_2O_5). A set of standards are then made in comparison tubes containing 0.2, 0.4, 0.8, 1.2, 1.6, 2, 4, 8, 12, etc., cc. in 50 cc. and to each of these is added 2 cc. of molybdate mixture. This affords a yellow color scale, the depth of tint being proportional to the amount of P_2O_5 present. When protected from evaporation these standards will keep for a long time.

To apply to water, evaporate 1 litre in platinum, add HNO_3, and evaporate to remove SiO_2. Repeat evaporation with HNO_3. Take up with dilute HNO_3, pour into a comparison tube, dilute with washings to 50 cc., add 2 cc. of molybdate mixture, mix and compare after a few minutes. The P_2O_5 gives its maximum color almost immediately; SiO_2, if present in solution, gives a coloration which deepens slowly, and then slowly pales. For equal amounts the SiO_2 color is deeper than that from P_2O_5.

Phosphor Bronze.—Wickhorst (J. Am. Chem. Soc., XIX., 396). For P dissolve 1 gm. in 15 cc. HNO_3 and 5cc. HCl, dilute, add excess of ammonia, pass H_2S filter and in the filtrate precipitate with Mg solution as usual. Wash the precipitate with dilute NH_3 solution containing a little $(NH_4)_2S$. Redissolve in dilute HCl and reprecipitate with ammonia.

Complete analysis.—Treat 0.5 gm. with 5 cc. HNO_3 and heat. When the reaction is over rub the residue with a rod, add water and filter, washing with dilute HNO_3. Heat the precipitate and filter slowly up to strong ignition, weigh $SnO_2+P_2O_5$. Fuse this with 0.5 gm. Na_2CO_3 and 1 gm. S (crucible covered) over a Bunsen burner, till excess of S is driven off. Cool, leach out with water, add ammonia, then 1 gm. HCl and precipitate cold with Mg mixture. Filter, dissolve in HCl and reprecipitate.

A little P_2O_5 may not remain with the SnO_2. In a duplicate sample, treated in the same way, the P_2O_5 may be determined by molybdate separation.

In the filtrate from the above, nearly neutralize with ammonia, add 5 cc. HNO_3, dilute to 150 cc. and separate Cu by electrolysis. Pb is also determined as PbO_2 on the other pole, in this operation. In the solution separate Fe and Zn by precipitating both with NH_4OH and $(NH_4)_2S$ Ignite rather cautiously at first, finally strongly to get a mixture of ZnO and Fe_2O_3. Dissolve in HCl, precipitate with ammonia and obtain Fe_2O_3; deduct from the weight of the two together to get ZnO.

Boric Acid.—Schneider (Chem. Ztg., XX., 822). The material is extracted with absolute alcohol under a reflux condenser, the solution cooled and filtered. (Raw meats, etc., may be extracted in a covered beaker on a water bath, then anhydrous Na_2SO_4 added to absorb water and again extracted.) The solution is distilled from a flask deeply immersed in the water of a water bath, the alcohol carrying over the B_2O_3

with it. Then add the distillate gradually to a solution of a weighed amount of fused Na_2CO_3, evaporate to dryness, ignite and weigh. From the difference of weights calculate B_2O_3.

Boric Acid.—De Koningh (J.Am. Chem. Soc., XIX., 385). Boiling a solution of strength of 2 gms. B_2O_3 in one litre when boiled showed practically no loss of B_2O_3 in the vapors unless the solution was much concentrated. On evaporating to dryness only about one eighth of the B_2O_3 was volatilized. The method used for the test was adding 50 per cent of glycerol and titrating with phenolphthalein indicator. To separate from P_2O_5, using a dilute solution and precipitating cautiously with $CaCl_2$, the solution containing a slight excess of Na_2CO_3, will leave B_2O_3 in the solution. Addition of $(NH_4)_2CO_3$ with ammonia will precipitate the excess of Ca. Then boiling the filtrate with excess of Na_2CO_3 to expel NH_3 affords a solution in which B_2O_3 may be estimated by titration. The Mg separation of P_2O_5 was also found to be successful. Some experiments in the use of NH_3 solution of Zn for separating the P_2O_5 are in progress.

Boric Acid in Foods.—De Koninck (J. Am. Chem. Soc., XIX., 55). So-called "glacialine," consisting of a mixture of 3 parts of the acid with one of borax, is frequently used. With uncooked eggs, add to 5 gms. of the sample one drop of NaOH (1:1), dry and incinerate. Boil the char with water and burn the residue again. Extract with water, unite the solutions, add a few drops of methyl orange and render barely acid with tenth normal H_2SO_4. Boil to expel CO_2, cool, add half its bulk of glycerine and titrate with N/10 NaOH, using phenol-phthaline as indicator. The presence of phosphates causes some interference and some allowance must be made for them. In 5 gms. of egg this allowance amounts to 3 cc. of N/10 NaOH. In milk 1 cc. of NaOH solution is used for 10 gms. of the sample.

Sulphur in Pig-iron.—Blair (J. Am. Chem. Soc., XIX., 114). A sample of pig-iron was received which gave no S by the evolution method. By the aqua regia method it showed 0.032 and 0.042 per cent. Bamber's method, which is recommended, gave 0.062 per cent. This method consists in dissolving (5 gms. or 6.878 gms.) in strong HNO_3, then adding 2 to 5 gms. KNO_3, evaporating to dryness in a platinum capsule and igniting. The mass is then treated with water containing a little Na_2CO_3 filtered, washed with weak Na_2CO_3, and the filtrate acidified with HCl, precipitating with $BaCl_2$ boiling.

Apparently sulphur exists in four different forms in pig-iron:

1. S evolved as H_2S on solution HCl.
2. S evolved as other compounds not absorbed by alkaline Pt solution or oxidized by Br or by $K_2Mn_2O_8$.
3. S unacted upon by hot HCl, but oxidized by HNO_3 or aqua regia.
4. S unacted on by HNO_3, HCl or aqua regia.

Sulphur in Irons.—Hertung (Chem. Ztg., February 6, 1897). The Wiborgh method is much used. Intensity of coloration of a paper or cloth soaked in Cd salt (evolution method), but may be erroneous from leakage of the apparatus, etc. The small amount used, 0.2 to 0.8 gm., is also an objection. The method described by E. F. Wood in Blair's book (passing with Cd salt and treating the CdS with I) is preferable.

De Konick's observation that H_2S is not materially oxidized by contact with air in the apparatus, is alluded to with approval from the author's experience.

Sulphur in Irons.—Boucher (Chem. News, LXXV., 121). The method proposed is one of the evolution methods in which the H_2S evolved by treating 10 to 20 gms. of the iron with HCl is caught in NaOH in a U tube. This solution is then run into an acid solution of Fe_2Cl_6 and the amount of ferrous salt formed titrated with standard $K_2Cr_2O_7$ solution.

Silicon in Silico-Spiegel and Ferro-Silicon.—Murray and Maury (J. Am. Chem. Soc., XIX., 138). The most successful method for speed and accuracy was: Add to 0.5 gm. of the finely pulverized material 50 cc. of water, 10 cc. conc. HCl, and 12 cc. H_2SO_4 (1:3). Heat to copious fumes of SO_3, cool, add 10 cc. HCl warm, and then 75 cc. of water. On heating there should be no effervescence from undecomposed material (if there is, evaporate again to fumes). Boil, filter, wash with HCl (1:1,) ignite and weigh; add H_2SO_4 and HF. Ignite and weigh again. Loss is SiO_2, calculate to Si.

Silicates.—Opening up. Jannasch (Zts. Anorg. Chem.). The silicate is mixed with 10 to 12 parts of pure $PbCO_3$, in a large platinum crucible and heated at first (15 to 20 minutes) with a low flame, then raised to fusion. The crucible should not be red hot for more than one-third its height. After 10 to 15 minutes the crucible is dipped directly into cold water. By tapping, etc., when cold, the mass can be removed. Dissolve in HNO_3, evaporate to absolute dryness and take up with HNO_3, filter. Precipitate the major part of the Pb by HCl, filter, evaporate with excess of HCl, filter and precipitate remaining Pb by H_2S.

Silica in Blast-furnace Slags.—Meeker (J. Am. Chem. Soc. XIX., 370.) 0.5 gm. of finely pulverized slag is placed in a 4 in. casserole. Cover with cold water (about 3 cc.) and stir to break up lumps. Then pour in 10 cc. conc. HCl, stirring vigorously to prevent sticking to the bottom.

As soon as the slag seems dissolved as much as it will, and before it is set to a jelly, pour in 40 cc. H_2SO_4 (1:1), stir well, wash off stirring rod, and then cover with a funnel. The funnel should have fused edges, and be of such a size as to rest upon the sloping inside of the casserole, and set down above the solution.

Place the casserole on a wire gauze, and boil rapidly until fumes of SO_3 begin to come from under the edge of the funnel. Cool, dilute somewhat, and clean off the funnel. Add about 10 cc. HCl and dilute until the casserole is as full as it can be conveniently. Cover with watch glass and boil gently one minute. Filter on pump. Wash five times with hot HCl (Gr. 1.10), and five times with hot water. Ignite and weigh.

The discussion of the reasons for this procedure must be consulted in the original paper. The plan was adopted in view of the presence of spinel (magnesium aluminate), which occurs frequently in these slags.

Carbon in Ferrochrome.—Breasley and Leffler (Chem. News, LXXV., 241). The method used consisted in mixing 0.5 to 1 gm. of

the finely powdered ferrochrome with 10 gms. $PbCrO_4$ which had been previously fused and then re-ground to powder; inserting in a porcelain boat which was placed in a porcelain combustion tube packed with CuO, etc., and then effecting combustion. The details of manipulation are all-important. The method given by Professor Arnold (Steel Works Analysis, p. 213) did not prove satisfactory. In a communication (C. N. LXXV., 263.) Professor Arnold states that the cause of failure with his process was due to defective furnace and unsuitable manipulation on the part of the authors.

Carbonic Acid by Iodometric Method.—Phelps (Zts. Anorg. Chem. XII., 431). The CO_2 freed from its combination by some non-volatile acid in a suitable flask is passed into $Ba(OH)_2$ solution. The excess of $Ba(OH)_2$ is then neutralized by standard solution of I until all is converted to $Ba(IO_3)_2$, and BaI_2. The excess of I is then titrated with normal As_2O_3 solution.

Estimation of Cyanogen.—Sharwood (J. Am. Chem. Soc., XIX., 400). A monograph on the determination of the various forms of cyanides likely to occur in the "cyanide extraction" of gold from its ores, using KI and NH_4OH as indicator—proposed by Deniges (Ann. Chim. Phys. [7] VI., 381).

Cyanide Solutions.—Ellis (J. S. C. I., XVI., 115). Various applications of methods already noticed are described. Particular attention is given to the reactions involved in the process of extraction of gold with the other (possible) constituents of the ore, etc. (Cu, Zn, etc.). The accurate determination of free KCy in presence of K_2ZnCy_2 K_2CO_3 and KOH is regarded by the author as an analytical problem hitherto unsolved. The $AgNO_3$ and KI method of titration is used.

Nitrous Acid Reaction.—Riegler (Zts. anal. Chem. XXXV., 677). Place 0.02 to 0.03 gm. crystallized naphthionic acid in a test tube, add 5 to 6 cc. of the liquid to be tested, shake well, then add 2 or 3 drops conc. HCl, shake thoroughly, then run in a little ammonia solution (20 to 30 drops), so that it forms a layer on the top. A trace of HNO_2 will show a rose-colored ring at the point of contact. On shaking the rose tint is spread through the solution. The author makes the test quantitative, ib., XXXVI., 306.

Nitric Nitrogen.—Copper zinc couple. Stock (J. S. C. I., XVI., 107). Granulated zinc is used, to this is added 2 to 3 drops of H_2SO_4 and 10 cc. of a 3 per cent. solution of $CuSO_4$ (crystals); after shaking (holding the stopper in) for a minute, the mouth of the bottle is covered with copper gauze, and Zn washed and drained, when it is ready for the addition of the water to be analyzed.

Analysis of Nitroglycerine.—Henry (Bull. Acad. Roy. Belg., XXXII., 266). The combustion has been made in the ordinary manner, when the explosive was completely soaked up in powdered CuO.

Iron containing Boron.—Warren (Chem. News, LXXV., 91). The compound of iron and boron may be readily produced by heating ferric borate to a red heat. Even fusing iron in contact with borax, as is sometimes done in metallurgical work, produces some of the boride, which

mingles with the iron. In some cases this may cause some errors in the analysis of such irons.

Coke, Sampling and Analysis.—Stock (J. S. C. I., XVI., 304). The necessity for a uniform method of sampling is very desirable. The method recommended is; when on cars to open the side doors and take portions from the top, middle and bottom of each car, collecting in this way, from say ten cars, a bulk sample of 3 to 5 cwt. This should be broken up to about macadam size, well mixed on clean iron plates, heaped together, and sampled after the regular fashion of mineral ore sampling, breaking smaller and smaller each time, until the sample is brought down to about 20 pounds, which will pass a ½-inch sieve, which is still further reduced on a bucking plate, and finally in a wedge-wood mortar. Too much working on the bucking plate will increase the percentage of ash by wearing off the plate. A 100 gm. sample should be taken for moisture determination when all the sample will pass a ⅜-inch sieve. A 500 gm. portion of the sample, after grinding finer, is dried, and portions of it used for determination of the other constituents. Drying for three hours in an air bath at 105° is sufficient to expel the moisture; 0.7 to 1 per cent. is the usual amount. The maximum amount which a coke can be made to hold is 19.17 per cent. A lot which had been long exposed to rain was found to contain 2.30 to 12.36 per cent., average 5.25. The method used for S determination is to mix 1 gm. of the pulverized and dried sample with about 1 gm. of half hydrated CaO [mixture of equal parts of CaO and Ca $(OH)_2$] moisten with 1 cc. of water, dry, and then heat in a muffle to bright red until all carbon is burned off. After cooling, the material is treated with 20 cc. water, and 5 cc. saturated Br water, 7.5 cc. HCl are then added, and after boiling five minutes the solution is filtered, the residue washed, and the filtrate, etc., precipitated boiling with $BaCl_2$ boiled half an hour, kept hot for three hours, filtered and washed, etc. For P, which usually runs 0.005 to 0.017 per cent., 10 gms. of the sample are burned to ash in a flat Pt tray, the ash ground in a mortar, and digested nearly boiling with 20 cc. of brominized HCl. The HCl is then evaporated off. After taking up with 20 cc. of water, and filtering, 15 cc. of strong ammonia is added, which is then neutralized with HNO_3; after adding a few drops of dilute ammonia, and again neutralizing with HNO_3, 2.5 to 3 cc. of strong HNO_3 are added, then 5 cc. of molybdate mixture is added suddenly. By constant shaking for five minutes, when the operation is conducted with a hot solution, the precipitation is complete, and the rest of the operation can be conducted in the usual manner. The author dries and weighs the yellow precipitate.

New Element.—Demarcay (C. Rend., CXXII., 728). By fractional crystallization of (fuming) HNO_3 solution of rare earths rich in samarium the author obtained a colorless nitrate of an apparently new earth, but little soluble in the cold. The primary spectrum gave lines different from those of Gadolinium and of Samarium, though weak lines of those elements were seen, showing that it had not been completely purified. The element is provisionally designated as Σ.

BOOK REVIEWS.

Missouri Geological Survey. Vol. XI. "Clay Deposits." By H. A. WHEELER.

This is the largest clay report which has ever been issued in the United States, and the extensive and varied character of the Missouri clays has given Prof. Wheeler an excellent subject for study. The report shows that there are within the State large beds of high-grade clay, which must be a source of great revenue at no very distant day. Detailed accounts are given of the china clay, flint and plastic fire clays, potters' clays, shales, paving-brick clays, etc. The flint clays are especially interesting from a chemical standpoint, as they seem to be mixtures of kaolinite and its amorphous variety, pholerite.

The special value of the report lies in the physical tests which have been made on a number of the samples studied. This is the first report issued in this country in which the foreign physical methods of study have been employed. This includes the determination of the plasticity, shrinkage in drying and burning, temperatures of incipient fusion, vitrification and viscosity, etc. The plasticity of clays is an important property and one which it is always desirable to give a numerical value to. In the Missouri work Wheeler has used the method devised by Olchewsky, which is based on the close relation that exists between tensile strength of the air-dried clay and its plasticity. The more plastic the clay the greater its tensile strength. This is determined by molding the wet clay into briquettes, which, when air-dried, are pulled apart in a cement-testing machine, and the number of pounds per square inch which is required to do this noted.

The report closes with chapters on prospecting clays, a bibliography of a number of the more important books on clay and a table of the more important American and foreign analyses.

The work will form a valuable addition to the literature on American clays, which, happily, is daily increasing, but it is unfortunate that the work contains so many typographical errors. H. RIES.

A Primer of the Calculus. By E. SHERMAN GOULD. New York, D. Van Nostrand Company. 91 pp., 17 plates. Price, 50 cents.

In this little volume, which forms No. 112 of the Van Nostrand Science Series, the author has succeeded in presenting the subject of the calculus in a very clear and lucid manner, as far as the first differentials of algebraic functions of one independent variable and their corresponding integrals are concerned.

The author has adopted the plan of entirely omitting any discussions as to the logical basis of the science, but plunges immediately into working formulas, first for differentiation and then integration. Appropriate examples illustrating the application of these formulas are then given, covering maxima and minima, areas of curves, volumes of solids, lengths of curves, areas of surfaces of revolution, centre of gravity, etc. A few remarks in regard to the limitations of the calculus form the final pages.

The work shows care in its preparation, for the subject is handled in a masterly way, very concisely and tersely stated, while the examples

selected to illustrate the various methods and points are well chosen and of an extremely practical nature. W. H. F.

The Elements of Physics. Vol. III., "Light and Sound." By EDWARD L. NICHOLS and WILLIAM S. FRANKLIN. New York, The Macmillan Company. 194 pp., 182 diagrams and illustrations. Price, $1.50

The concluding volume of the series of three on "The Elements of Physics" by the above authors maintains the high standard set by its predecessors.

The opening chapter presents the wave theory of light and of sound and describes historically the methods employed for determining the velocity of propagation of each.

Under the subject of Waves the authors present discussions relating to longitudinal and transverse waves, gradually leading up to the modern idea of Wave Front and touching upon the subject of Shadows.

Reflection and Refraction are next taken up and considered in a very clear and complete way, aided by many diagrams.

Chapters IV., V. and VI., covering 28 pages, touch in order upon lenses and systems of lenses; imperfections of lenses and methods of correcting the same with examples of various lens systems used in practice; simple optical instruments under which, after an introduction as to the essential features and defects of the human eye, are treated the camera, magic lantern, microscope, telescope, spy-glass and opera-glass.

The next topic dwelt upon is Dispersion, allowing the authors to discuss the spectrum and spectroscope, followed by an excellent chapter on Interference and Diffraction.

The subjects of Color and Photometry, an excellent treatment on Polarization and Double Refraction, together with a clear exposition of Radiation, leave the remainder of the book to be entirely devoted to Sound.

Loudness, Pitch and Timbre is the heading of the first chapter on Sound, followed by one on Free Sonorous Vibrations, in which the authors touch upon the action of columns of air, vibrating strings, diaphragms and manometric flames.

Next the authors take up questions of Damping, Impressed Vibrations and Resonance and Hearing.

The final chapter, on Musical Intervals and Scales, is a very compact and terse statement of the theory of music.

In this volume much repetition has been avoided by considering Light and Sound together in many of the discussions and only treating them separately where absolutely necessary.

The series as a whole fills a want which has heretofore existed, *i. e.*, a text-book for students who possess a good working knowledge of the calculus.

From this standpoint no one can say that the authors have not accomplished what they set out to do. W. H. F.

A Dictionary of the Names of Minerals, including their "History and Etymology." By PROFESSOR ALBERT H. CHESTER. John Wiley & Sons, 53 East Tenth Street, New York City; and Chapman & Hall, Limited, 11 Henrietta Street, Covent Garden, London, W. C., England. 8vo, cloth. Price, $3.50.

Professor Chester was well qualified by previous work and as the possessor of a fine mineralogical library to undertake the critical study of the origin and present importance of the various names given to minerals, and the book before us is the result of many years of patient work and extensive correspondence. It is rather, however, a dictionary of the English forms of names, as the five thousand (approx.) names given do not, in general, include the foreign forms and spellings of the common names, such as Kieselzenkerz Atakamit, Schwerspath, etc.

The general scope and style of the work is best illustrated by one or two examples, for instance:

Adularia. *E. Pini*, 1783, Pini St. Gott., 57 (adulaire) from the Adula Mts., erroneously supposed to be the range containing Mt. St. Gotthard, its locality. The transparent variety of orthoclase often showing pearly and opalescent reflections.

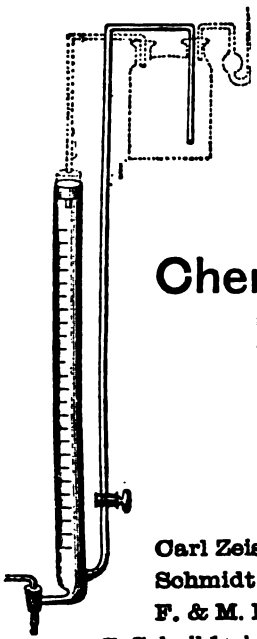
Hortonite. A. Dufrenoy, 1859, Duf. Min. IV., 424, probably in honor of Dr. William Horton. A steatitic pseudomorph of pyroxene from Orange county, N. Y.

That is, the attempt is made to give the author's name, the date he published the name, the work in which published, the first form of the name and its derivation, and finally a short description.

Objection may sometimes be made to Professor Chester's choice of species, variety and synonym. These merge into each other and the dividing lines depend very largely upon circumstances. The larger the collection the greater the freedom given to the variety. This feature, however, is not the essential one, and the great value of the book to mineralogists will be to assist in the exclusion of names shown to be errors, to prevent repetitions of names once used and to furnish a reference to the original description of the substance.

The work is carefully printed on good paper and should be owned by all collectors and lovers of minerals.

ALFRED J. MOSES.



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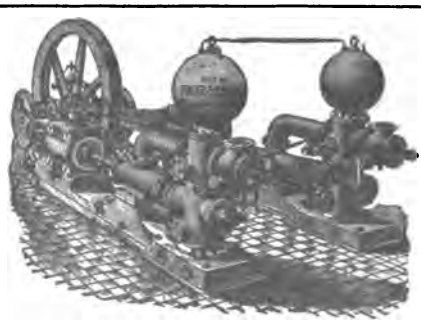

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1897.

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NOTE.—Correspondence concerning dues and other clerical details of the work of the Association may be conveniently addressed to MR. FRANCIS W. HOADLEY, Assistant to the Secretary and Treasurer, No. 12 West 31st St., New York City.

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F. R. HUTTON, ...	1899
HOWARD VAN SINDREN, ...	1900
W. B. PARSONS, ...	1901
WM. ALLEN SMITH, ...	1902

CONTENTS.

	PAGE
Officers of the Association,	3
Standing Committees,	4
List of all Graduates by Classes,	7
List of Members of Alumni Association (alphabetical),	19
List of Honorary Members,	92
List of Graduates not Members of Alumni Association,	93
List of Members Classified by States and Towns,	109
Constitution of Alumni Association,	115

SUMMARY.

All Graduates,	1028
Members of Alumni Association,	556
Honorary Members,	6
Life Members,	24
Associates,	13
Other Graduates,	350

(REVISED TO MARCH, 1897.)

LIST No. 1.

Contains the names of all Graduates and Members of the Alumni Association grouped by classes from the beginning. The details as to residence and Professional Occupation are given in the second or alphabetical list for convenient reference.

(REVISED TO MARCH, 1897.)

CLASS LIST

OF

GRADUATES AND MEMBERS

OF THE

ASSOCIATION OF THE ALUMNI.

[NOTE.—Where the name is followed by a date, it denotes that the person is no longer living, and the date is the year of the death.]

1867.

Adams, J. M., 1892.
Bridgham, S. W.
Bronson, E. S.
Brown, F. G.
Church, J. A.
Cornwall, H. B.
Giddings, E. E.
Gracie, C. K., 1891.
Hale, A. W.
Harding, G. E.*
Harmer, T. H.
Petit, F. M.
Tuttle, W. W.
Van Lennep, D.

1868.

Barnard, A. P.
Baxter, G. S.
Carson, J. P.
Chester, A. H.
Coursen, G. H.
Geer, G. J., Jr.
Hanna, G. B.
MacMartin, A., 1881.
Melliss, D. E.*
Moffatt, E. S., 1893.
Parsons, G. H.
Pennington, J. P.*
Pistor, W.
Platt, C. S.
Robertson, K.
Shack, A. P.
Schermerhorn, F. A.
Smith, L.
Smith, W. A.
Stalknecht, F.
Van Arsdale, W. H.
Wheeler, M. D., 1889.

1869.

Blossom, T. M., 1876.
Bruckman, F.
Campbell, A. C.
Delafield, A. F.*
Hooker, W. A.
Huntingdon, C.
Irving, R. D., 1888.
Jenney, W. P.
Munroe, H. S.
Nettre, L. R.
Newton, H., 1877.
Potter, W. B.
Randolph, J. C. F.

1870.

Haight, O., 1891.
Ingersoll, W. H.
Knapp, J. A.
Lilienthal, J. L., 1893.
Lindsley, S.
Parrot, E. M.
Terhune, R. H.
Van Wagenen, T. F.
Waller, E.

*Associate.

1871.

Fales, W. E. S.
Goldschmidt, S. A.
Gordon, J.
Ricketts, P. de P.
Riggs, G. W.
Roberts, G. S.
Robertson, R. S., Jr.

1872.

Austen, P. T.
Jenney, F. B., 1876.
McDowell, F. H.
Sloane, T. O'C.
Wendt, A. F., 1893.

1873.

Canfield, F. A.
Colton, C. A.
Mott, H. A., 1896.
Webb, H. W.
Williams, J. T., Jr.

1874.

Allen, C. S.
Benedict, W. de L.
Cameron, J. G. M., 1889.
Ledoux, A. R.*
Lillie, S. M.
Murray, G.
Olcott, E. E.
Rees, B. F.
Rhodes, F. B. F.
Williams, F. H.

1875.

Ihlseng, M. C.
Iles, M. W.
Jackson, C. E.
Joy, D. A., 1888.
Lamson, R., 1876.
Leavens, H. W.
Macy, A., 1891.
Noyes, W. S.
Pfister, P. C.
Putnam, B. T., 1886.
Rees, J. K.
Rolker, C. M.
Russell, S. H., 1889.
Stewart, H.
Thompson, M. S.
Tucker, J. H.
Vanderpoel, F.
Wells, J. S. C.
Wetmore, E. A.
Wright, A. A.

1876.

Austin, T. S.
Bruen, F. E., 1884.
Cornwall, G. R.
Craven, F. C., 1890.
Foote, H. C., 1888.
Garrison, E. H.
Gratacap, L. P.
Hall, R. W.
Hamilton, S., Jr.
Holbrook, F. N.
Hoyt, W. L.
Hunt, F. F.
Hutton, F. R.
King, C.
Lord, N. W.
Love, E. G.
Maghee, J. H.
Morewood, H. F.
O'Grady, J. W., 1890.
Randolph, J. F.
Ross, W. C.
Schneider, A. F.
Tilden, G. C.
Van Blarcom, E. C.
Walbridge, A. C., 1892.
Wardlaw, J. R., 1891.

1877.

Barros, L. de S.
Barus, C.*
Beard, J. T.
Behr, E.
Buckley, C. R.
Cady, L. B.
Canfield, A. C.
Cauldwell, J. B.
Clark, H. G., 1881.
Colby, C. E.
Constant, C. L.
Cornell, G. B.

*Associate.

Floyd, F. W.
Helleberg, F. S., 1833.
Hildreth, W. E.
Ihlseng, A. O.
Jordao, J. N. P.
Kelly, W.
Mackintosh, J. B., 1891.
Martin, E. W.
Murphy, J. G.
Nichols, R.
Norris, D. H.
Priest, J. R., 1880.
Radford, W. H.
Reed, S. A.
Rogers, C. L.
Sage, E. E.
Smeaton, W. H.
Smythe, R. M.
Thacher, A.
Van Boskerck, R. W.
Waterbury, C. R.

1878.

Adams, W. J.
Benjamin, M.
Blydenburgh, C. E.
Booraem, R. E.
Brinkerhoff, G. C.
Butler, W. P.
Cushman, A. R.
Davis, J. W.
Devereux, W. B.
Downing, O. P.
Drummond, I. W.
Eliot, W. G.
Fernekes, A., 1884.
Haas, H. L.
Hasegewa, Y.
Hodges, H. A., 1883.
Holden, E. H.
Hollis, W.
Johnson, E. M.
Johnson, G. H.
Karr, C. P.
Lawrence, B. B.
Lyman, F.
Matsui, N.
McCulloh, E. A.
Morewood, G. B.
Morris, G. W., 1895.
Munsell, C. E.
Murphy, H. M.
Nambu, K.
Newberry, S. B.
Noyes, J. A.
Olmstead, O. F., 1881.
Owen, F. N.
Palmer, C. E.
Parker, R. A.
Pazos, V. F.
Perry, N. W.
Strieby, W.
Willis, B.

1879.

Bolton, R.
Britton, N. L.
Cloud, L. G.
Cornwall, H. C.
Deluze, L. P.
Eastwick, G. S.
Haffen, L. F.
Harker, C. S.
Hathaway, N.
Hollerith, H.
Hollick, C. A.
Johnson, I. B.
Johnston, R. A., 1895.
Koch, E. C.
Leggett, T. H.
Ludlow, E.
Marsh, C. W.
Mathis, T. S.
Mayer, R. E.
Merwin, H. J.
Milliken, G. F.
Munroe, O. M.
Neftel, K.
Nesmith, J.
Noble, C. M.
Reed, W. B. S.
Rhodes, R. D.
Rutherford, F. M.
Sheldon, G. H., 1889.
Starr, H. F.
Stewart, F. B., 1879.
Stone, G. C.
Suydam, J. R., Jr.
Williams, G. W.

1880.

Beebe, A. L.
Benjamin, F. P., 1893.
Browning, F. D., 1885.
Browning, J. H. B.*
Brugman, W. F.
Butler, N.
Churchill, A. D., 1896.
Clark, E. P.
Elliott, W.
Engel, L. G.
Francke, R. O.
Garlichs, H.
Greene, W. U.
Greenleaf, J. L.
Hallock, A. P.
Hendricks, H. H.
Hooper, L. M.
Hopke, T. M.

*Associate.

Hudson, E. H.
Klepetko, F.
Kunhardt, W. B.
Mattison, J. G.
Meissner, C. A.
Merritt, J. H.
Navarro, J. A.
Parker, A. McC.
Parks, J. R.
Robinson, H. A.
Ruttman, F.
Singer, G.
Singer, G. H.
Smalley, W. A., 1886.
Smith, M.
Tonnelê, T.
Torrey, C. H., 1895.
Walker, J., Jr.
Wheeler, H. A.

1881.

Andresen, C. A.
Aschman, F. T.
Bleecker, C. P.
Braschi, V. M.
Bush, E. R.
Chazal, P. E.
Colby, A. L.
Curtis, C. G.
Douglas, E. M.
Dunham, E. K.
Elliott, A. H.
Furman, H. V. F.
Griswold, W. T.
Hemmer, F. A.
Judd, C. B.
Leary, D. J.
LeBoutillier, C.
Ledoux, A. D.
Little, W. P.
Meserole, W. M.
Neymann, P.
O'Connor, M. J.
O'Connor, T. D.
Pitkin, L.
Raymer, G. S.
Richmond, W. T.
Roberts, A. C.
Sawyer, C. P.
Share, W. W.
Starr, C. D.
Stearns, T. B.
Swain, A. E.
Tuttle, E. G.
Van Sinderen, A. H.
Vulté, H. T.
Williams, W. F.
Wiechmann, F. G.
Wilson, H. M.

1882.

Calman, A.
Conant, T. P., 1891.
Cooper, W. H.
Crocker, F. B.
Dougherty, O. V., 1889.
Downes, S. B., 1895.
Downs, W. F.
Emrich, A. F., 1893.
Falk, D. B.
Feuchtwanger, H.
Fitch, C. L.
Going, C. B.
Hill, W.
Illig, W. C., 1894.
Joüet, C. H.
Mesa, A. E.
Moses, A. J.
Oothout, E. A., 1894.
Page, W. S.
Parsons, W. B.
Payne, C. Q.
Porter, J. B.
Powers, C. V. V.
Sands, F.
Shumway, W. A., 1892.
Staunton, W. F.
Stockwell, N. S., 1888.
Toucey, D. B.
Traphagen, F. W.
Vondy, R. H.
Wainwright, J. H.
Wainer, A. G.
Ward, N. R.
White, W. S.
Wilson, W. A.
Wittmack, C. A.
Young, E. L.

1883.

Abeel, G. H.
Adams, R.
Ayestas, A.
Balch, S. W.
Banks, J. H.
Bardwell, A. F.
Brereton, T. J.
Brewster, H. D.*
Bullman, C.
Carrére, J. M.
Channing, J. P.
Endicott, G., 1889.
Ferrer, C. F.
Ferris, J. C.
Fiallos, E. C.
Haasis, D. F.
Humbert, W. S.
Lilliendahl, A. W.

*Associate.

Mac Teague, J. J.
McKenna, C. F.
Oxnard, J. G.
Painter, G. E.
Paraga, C. F.
Peele, Robert.
Powell, F.
Randolph, E.
Renault, G.
Rich, J. M.
Richardson, J. C.
Ridsdale, T. W.
Suter, G. A.
Tibbals, G. A.
Tower, A. E.
Walker, A. L.
Weed, W. H.

1884.

Adams, W. C.
Alden, H. C.
Baldwin, W. M.
Barnard, E. C.
Barratt, E. G.
Bodelsen, O.
Brinley, J. R.
Bryce, W.
Buckingham, F. E.
Burritt, W. W.
Corcoran, J. T.
Del Calvo, F.
Duncan, W. P., 1889.
Dusenberry, W. T.
Easton, L. C.
Fahys, G. E.
Fitch, J. H.
Fitzgerald, G. E.
Fowler, S. S.
Glover, C. G., 1888.
Gosling, E. B.
Griffin, S. P.
Gross, L. N.
Horn, J. T.
Kemp, J. F.
Lamb, A. J.
Luttgen, E.
McGenniss, J. W., Jr., '90.
McKim, R. A.
McLoughlin, C. S.
Miller, C. W.
Moeller, W., 1897.
Moran, D. E.
Morgan, W. F.
Mulford, R.
Napier, A. H., 1895.
Newberry, W. E.
Newbrough, W.
Nolan, T.
Northrop, J. I., 1891.
Nye, A. C.
Painter, C. A.
Pearis, C. F.
Pellew, C. E.
Post, A. S.
Powers, L. J.
Proctor, W. R.
Reckhardt, D. W.
Roeser, F.
Rood, R. G.
Rowland, C. B.
Rupp, P., Jr.
Schöney, E., 1888.
Sherman, F. D.
Slack, C. G.
Smedberg, H. A.
Snook, T. E.
Speyers, C. L.
Tibbals, S. G.
Value, B. R.
Walbridge, F. K.
Wood, G. E.

1885.

Amy, E. J. H.
Barkley, H. F., 1895.
Bemis, F. P.
Brennan, A. J.
Bush, W. F.
Cary, G.
Clark, F. S.
Cozzens, H.
Crowell, C. B.
Detwiller, C. H.
Doolittle, C. H.
Dwight, A. S.
Eddie, E. C.
Engelhardt, E. N.
Graff, C. E.
Hart, B.
Hawkes, E. McD.
Hildreth, R. W., 1896.
Hollis, H. L.
Huntington, F. W.
Ingram, E. L.
Johnson, A. G.
Lacombe, C. F.
Lee, G. B.
Mannheim, P. A. L.
Marié L.
Meyer, H. H. B.
Merrill, F. J. H.
Miller, C. L.
Moldehnke, R. G. G.
Noble, L. S.
Norris, R. V. A.
Page, G. S.
Pierce, H. N.
Polledo, Y. Y.
Sanders, W. E.
Shope, H. B.
Starek, E.
Struthers, J.
Thomas, F. M.
Titus, W. H.
Van Cortlandt, E. N.
Watson, F. M.
Whitman, E. P.
Wiltsie, E. A.
Woolson, I. H.

1886.

Agramonte, E., Jr.
Agramonte, J. C.
Bell, H. M., Jr.
Berry, W. G.
Casey, E. P.
Conant, H. D.
Edwards, R. M.
Frankfield, E.
Good, G. McC. H.
Horne, W. D.
Howe, E.
Janeway, J. H.
Jenks, A. W.
Kissam, H. S.
Lederle, E. J.
Lee, H. C.
Newhouse, E. L.
Norton, L. H.
Ormsbee, J. J.
Osterheld, T. W.
Peck, S. B.
Porter, H. H., Jr.
Ryon, A. M.
Spooner, A. N.
Stodder, R. H., 1887.
Stuart, W. H.
Thompson, H. C.
Trowbridge, S. B. P.
Van Brunt, A. H.
Von Nardroff, E. R.
Wallace, W. J.
Wheatley, J. Y.
Wilson, C. E.

1887.

Aldridge, W. H.
Appleby, W. R.
Bellinger, H. P.
Bien, J. R.
Burns, A. L.
Burns, E. Z.
Butler, W. C.
Church, E. D.
Cole, H. M.
Congdon, E. A.
Cox, J. S., Jr.
Darwin, H. G.
Davis, C. H.
Donnell, H. E.
Ferguson, W. C. A.
Gage, S. E.
Goldsmith, B. B.
Gudeman, E.
Heinsheimer, A. M.
Huntting, H. O.
Jacobs, D. M.
Jacobs, S. J.
Jeup, B. J. T.
Lahey, J.
Lahey, R.
Luquer, L. McI.
Lusk, G.
MacKaye, H. S.
Mannheim, H. C.
Marsh, J. R.
Middleton, J.
Moeller, R.
Muller, G.
Nichols, H. P.
Primelles, J. A.
Restrepo, C. C.
Rice, G. S.
Rowland G.
Rutherford, L. H.
Schieffelin, W. J.
Seligman, J. G.
Simonds, F. M.
Slade, R. E.
Stanton, F. McM.
Staunton, J. A., Jr.
Stevens, A.
Tower, F. W.
Trask, G. F. D.
Tyler, W. L.
Warner, J. L.
Wels, P. O.
Wertheimer, L.

1888.

Allen, R. L.
Appleby, J. S.
Baker, G. L.
Bartlett, F. R.
Bechstein, C. A.
Beckwith, C. E.
Berry, G.
Colt, S. B.
Comstock, C. N.
Dodge, F. D.
Dodsworth, W. A.
Dow, A. W.
Fisher, W.
Frank, J. W.
Gardner, W. D.
Herbert, O. B.
Hopke, F. E., 1890.
Jones, W. D.
Koen, J. J.
Lenox, L. R.
Lipps, H., Jr.
McIlvaine, A. R.
Maclay, J.
Miller, R. P.
Morgan, J. L.
Munoz del Monte, A. C.
Parker, O. B., 1891.
Parsons, H.
Percival, G. S., 1892.
Perkins, T. S.
Schumann, C. H.
Shriver, H. T.
Smith, F. P.
Smyth, C. H., Jr.
Stoughton, A. A.
Taylor, J. B.
Tucker, A.
Van Dyck, E.
Van Volkenburgh, E.
Volckening, G. J.

1889.

Wampold, L.
Ward, D. W.
Atha, H. G.
Berry, G.
Brown, R. G.
Cramer, S. W.*
Cromwell, J. W.
Denton, F. W.
Dresser, D. LeR.
Eastwick, E. P.
Eilers, K. E.
Ellis, A. V. H.
Escobar, F.
Fearn, P. LeR.
Fowler, A. C.
Freedman, W. H.
Gifford, S. D.
Griffith, V. C.
Griggs, W. E.
Guiterman, E. W.
Harrington, T. H.
Harris, E.
Heinze, F. A.
Holt, M. B.
Ives, A. S.
Jopling, R. F.
Luquer, T. T. P.
Mahony, A. S.
Mapes, C. H.
Mason, C. S., 1889.
Massa, C. G.
Matthews, C. T.
Monell, J. T.
Mosley, R. K.
Oseransky, I. H.
Piez, C.
Post, A. Van Z.
Preston, W. E.
Provost, A. J., Jr.
Provot G.
Raymond, R. M.
Raynor, R.
Rogers, O. L.
Schroeder, J. L.
Skidnore, S. T.
Small, F. M.
Smith, A.
Smith, F. M.
Stoughton, C. W.
Waters, G. S.
Wedeking, E. H.
Weekes, E. F., 1893.
Weeks, W. H.
Whitlock, H. P.

1890.

Andrews, S. W.
Beckwith, G. A.
Beelen, H.
Betts, R. T.
Black, A. L.
Blake, E. M.
Book, D. D.
Bradley, S. R.
Buckland, W. A.
Cairns, F. I.
Carson, J.
Clark, D. L.
Clayton, W. R.
Colton, F. G.
Connell, H. R., 1895.
Coykendall, T. C.
Davis, W. M.
Deghueé, J. A.
Douglas, J. S.
Ferguson, G. A.
Fisher, L. W.
Foyé, A. E.
Gildersleeve, A. C.
Gould, E. L.
Gudewill, C. E.
Hart, C. H.
Hewlett, J. M.
Hicks, G. J., 1891.
Hinman, B. C.
Hooper, F. C.
Hoyt, J. S.
Hurlburt, E. D., Jr.
Jarmulowsky, M.
Jones, J. T.
Kohn, R. D.
Korn, L.
Levy, A. L.
Lichtenstein, E. G.
Lowndes, W. S.
McKleroy, W. H.
Mann, H. B.
Massa, L. F.
Meikleham, T. M. R.
Montenegro, M. R.
Parker, H. C.
Pearce, R.
Pelton, H. C.
Portuondo, J.
Post, W. S.
St. John, T. M.
Steers, J. R.
Thorne, W. L.
Warren, C. P.
Welch, A. McM.
Welsh, H. F.

1891.

Anderson, Geo.
Bliss, C. P.
Bookman, S.*
Blossom, F.
Boecklin, W.
Boyd, R. C.
Brosnan, F. X.
Cristy, E. B.
Dunn, G. S.
Eberhardt, Wm. G.
Goodwin, E.
Hawley, J. F.

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Holter, N. B.
Hornbostel, H. F.
Keeler, F. S.
Kinsey, F. W.
Langthorn, J. S.*
Leary, Geo.
Lilliendahl, F. A.
Livingston, A. R.
Mahl, J. T.
Mann, C. R.
Miller, E. H.
Mora, M. L.
Owens, R. B.
Raymond, A.
Skinner, E.
Strout, W. A.
Thomas, F. C.
Totten, G. O., Jr.
Tuska, G. R.
Warren, L.
Watson, R. B.
Wiener, Wm.

1892.

Ansbacher, L. A.
Anthon, A.*
Bergen, C. H.
Bolles, R.
Burden, H., 2d.
Casamajor, G. H.
Clark, Edmund.*
Clarke, W. C.
Covell, E. C.
Curtiss, C. C.
Dolan, C. F.
Dufourcq, E. L.
Durham, E. B.
Dutcher, B. H.
Fenner, C. N.
Friedman, S.
Gillette, H. P.
Granger, A. D.
Harrison, N.
Hay, A.
Herckenrath, W. A.
Jackson, O.
Kletchka, J. J.
Knox, C. E.
Livingston, G.
Longacre, L. B.
Lord, F. R.
McIlhiney, P. C.
McKinlay, J. B.
Meisel, F. C. A.
Merz, E.
Parmly, C. H.
Pierce, F. E.
Reckhart, G. F.
Reese, W. W.
Ries, H.
Rosenthal, A.
Savage, S. M.
Southard, G. C.
Temple, S. J.
Towart, J.
Van Ingen, D. A.
Werner, H. C.
White, R. D.
Windecker, C. N.
Windolph, A. P.

1893.

Agelasto, M. A.
Agramonte, I. E.
Aldrich, C. H.
Ayers, W. C.
Behrmann, G. W.
Bossange, E. R.
Brooks, W. F.
Canfield, M. C.
Clark, G. H.
Covell, W. S.
Foster, R. G.
Gonzalez, A.
Gregory, L. E.
Hankinson, A. W.
Harte, C. R.
Haskell, H. G.
Hoyt, R.
Hume, F. T.
Hyde, F. S.
Jones, J. E.
Kurtz, E. L.
Langmuir, A. C.
Liebmann, A.
McKee, H. S.
Macy, V. E.
Malukoff, A. J.
Matthew, W. D.
Newton, T. M.
Oakes, J. C.
Pederson, F. M.
Pomeroy, W. A.
Post, R. B.
Prince, A. D.
Provot, F. A.
Putnam, B. R.
Reynolds, M. T.
Robinson, F. G.
Schroter, G. A.
Smith, H. A.
Thompson, S. C.
Tilghman, H. A.
Tuttle, W.

1894.

Acken, B. A.
Barnett, L. K.
Black, Adolph.
Bogert, M. T.
Chapman, A. W.
Clark, Leroy.
Cokefair, F. A.
Emery, H. G.
Fellows, Wm. K.

*Associate.

Folger, E. P.
Frisbee, H. D.
Fuentes, Paul.
Greene, D. J.
Hamilton, F. C.
Hanson, R. C.
Harold, A. P.
Hass, E. F.
Jacobs, H. A.
Jones, E. M.
Kastner, J. C.
Leeming, T. L.
Libaire, E. W.
McNeil, C. R.
Masters, H. K.
Messiter, E. H.
Meyer, Joffe.
Mears, G. K.
Morris, B. W., Jr.
Murchison, K. M.
Munroe, M.
Osterberg, Max.
Perrine, Geo.
Pope, J. R.
Prince, J. L.
Rennard, J. C.
Rittenhouse, C. T.
Searle, C. D.
Seldner, R.
Self, E. D.
Sherman, G. F. G.
Smith, W. F.
Steinam, J. L.
Stratton, Alex.
Taintor, W. N.
Tennille, G. F.
Tompkins, J. A.
Vail, L. H.
Vanderbilt, W. D.
Vatable, J. J.
Walker, H. V.
Ware, F. B.
Westervelt, W. Y.
White, T. G.

1895.

Alexander, J. A.
Andrews, W. C.
Archer, G. F.
Albertson, A. H.
Barnett, L. H.
Bayles, F. P.
Baldwin, D. H.
Binion, Joshua.
Benedikt, V. M.
Bijur, Jos.
Buck, H. W.
Bultman, H. D.
Candler, D. W.
Carter, B. P.
Coykendall, E.
Cox, E. V.
Dobbins, Max.
Durham, H. W.
Dewey, F. H.
Evans, I. N.
Fintel, E. A. von, Jr.
Fletcher, G. W.
Foerster, David.
Fox, M. J.
Gottsberger, B. B.
Gartensteig, Chas.
Grace, F. J. M.
Herzig, C. S.
Huntoon, L. D.
Horton, C. F.
Hadden, H. S.
Jarman, Z. H.
Johnstone, W. B.
Jobbins, F. H.
Janes, E. H.
Kirby, G. T.
Kraemer, H.
Leo, R. L.
Lum, C. H.
McKinlay, W. B.
Miller, S. O.
Moisseieff, L. S.
Moses, P. R.
Moeller, E. J.
Mulliken, H. B.
Natkins, I.
Ormsbee, A. F.
Peugnet, C. P.
Pinkham, H.
Portuondo, J. M.
Pell, F. L.
Peppmüller, R. H.
Perrin, H. C.
Pilcher, L. F.
Reeve, F. C.
Riker, C. L.
Spaulding, M. B.
Shattuck, L. R.
Shrady, C. D.
Sutton, F.
Stewart, J. H.
Schell, R. M.
Seward, J.
Thomas, E. H.
Tucker, S. A.
Walker, F. W.
Whiting, L.

1896.

Arden, John Lorillard.
Auryansen, Frederick.
Benoliel, Solomon D.
Burrill, Percy Morris.
Carney, Edward Joseph.
Clark, Allen Jay.
Comstock, Fredk. Lacy.
Darrach, James Musgrave Aertsen.

Derleth, Charles, Jr.
Dowie, Horace.
Drasel, Charles.
Franklin, Lindley Murray, Jr.
Godley, Richard David.
Goldsmith, Goldwin.
Hawks, Herbert Durand.
Heye, George Gustav.
Holden, Edwin Chapin.
Hyatt, Chas. Edward.
Hyde, Henry St. John.
Lowenstein, Joseph,
McCaffery, Richard Stanislaus.
McConway, William Lytle.
MacGahan, Paul.
MacGregor, Donald.
Hesselbach, Chas. Valentine.
Metzger, Arthur.
Monell, Ambrose, Jr.
Montgomery, Hardman Philips Alan.
Morse, George Tremaine.
Necarsulmer, Edward.
Of, Charles.
Painter, Robert Kitching.
Palmer, George Quintard.
Parker, Richard Alexander.
Pemoff, Joel.
Perry, Charles Langdon.
Prosser, Herman Alfred.
Raymond, William Oakley.
Regan, Geo. W.
Riedel, Arthur Emil.
Rodenburg, Charles.
Serber, David Charles.
Sergeant, Elliot Mathews.
Shire, Edward Isaac.
Slichter, Walter Irvine.
Stern, Henry.
Tachau, William Gabriel.
Thyng, William Stevens.
Toch, Max Bernard.
Tompkins, Edward De Voe.
Townsend, Samuel George Fitzhugh.
Tubby, Josiah Thomas, Jr.
Uhlig, William Cullen.
Van Benthuysen, Boyd.
Van Gelder, Arthur Pine.
Van Vleck, Joseph, Jr.
Wells, Dana Clemmer.
Witherell, Charles Shepard.
Woodruff, George William Lane.

LIST No. 2.

This list embraces the members of the Alumni Association of the School of Mines under the Constitution of that body. It is urged that all graduates of the School should list themselves under this group. Names not found here are grouped in List No. 3, which includes graduates who are not also members. All graduates are requested to try to make and keep this list correct and accurate.

(REVISED TO MARCH, 1897.)

MEMBERS

OF THE

ALUMNI ASSOCIATION OF THE SCHOOL OF MINES.

A.

ABEEL, GEORGE HOWARD, E. M., ... 1883.
Box 642 Hurley Iron Co., Wis. Also 5 East 124th St., New York City.

1883-84, Chemist Iron Cliffs Co., Negaunee, Mich. 1885-88, Assistant Manager Cliffs Co., Negaunee, Mich. 1886-1887, Supt. Negaunee Gas Light Co., Mich. 1888-89, Manager Ironton Iron Mining Co., Bessemer, Mich. 1888-89, Agent Pilgrim Mining Co., Bessemer, Mich. 1889, Supervisor Bessemer Township, Gogebic Co., Mich. 1889-92, Agent Ruby Iron Mining Co., Bessemer, Mich. 1888 to 1895, General Manager of Montreal River Iron Mining Co., Hurley, Wis. 1892 to 1894, Vice-President First National Bank, Hurley, Wis. 1892 to date, Vice-President Wisconsin Mining Supply Co., Hurley, Wis. 1893, Vice-President and General Manager Section 33 Iron Mining Co., Hurley, Wis. 1894, Consulting Engineer Newport Mining Co., Supervisor, Town of Vaughn.

ADAMS, RANDOLPH, E. M., ... 1883.
Broken Hill, N. S. Wales, Australia.

1884-87, Assistant Superintendent and Superintendent of the Silver King Mine, Silver King, Arizona. 1887-91, engaged in Australia as Mining Superintendent and Mining Expert, and now Manager of the Central Broken Hill Mine, Broken Hill, N. S. Wales, Australia.

AGRAMONTE, EMILIO, C. E., ... 1886.
110 Lexington Avenue, New York City.
Engineer Department of Public Works.

ALDRIDGE, WALTER HULL, E. M., ... 1887.
Manager United Smelting and Refining Co., East Helena, Mon.

Beginning July, 1887, Assayer at Colorado Smelting Co., Pueblo. At different times, Chemist of Colorado Smelting Co., Pueblo. August, 1890-91, Assistant Superintendent and Metallurgist of Colorado Smelting Co., Pueblo. Assistant Manager United Smelting and Refining Co. 1893, Manager as above.

ALLEN, CHAS. SUMNER, PH. B., M. D., . . . 1874.
Practicing Physician.

ALLEN, ROBERT LAWRENCE, A. M., E. M., . . . 1888
102 Cambridge Place, Brooklyn, N. Y.

AMY, ERNEST JULIUS HYACINTHE, A. B., E. M. . . 1885.
General Manager, San Juan S. and M. Co., Durango, Colo.

1885–86, Chemist and Assayer at works of the San Juan and N. Y. M. and S. Co., at Durango, Colo., with the exception of three months' professional visit to Old Mexico. 1886–87, Assistant Manager of the San Juan and N. Y. M. and S. Co., at Durango, Colo. 1887–88, Manager of the Hazleton Mountain Mining Co., at Silverton, Colo. 1888 to April 1, 1890, Assistant Manager of Works of the San Juan Smelting and Mining Co., at Durango, Colo. (The S. J. S. and M. Co. being formed by the consolidation of the S. J. and N. Y. M. and S. Co., of Durango and the Hazleton Mt. Mfg. Co., of Silverton, Colo.) Since April 1, 1890, General Manager of the San Juan Smelting and Mining Co., at Durango, Colo.

ANDREWS, SAMUEL WAKEMAN, JR., PH. B., . . 1890.
Andrews, Waters & Sherwin, 35 W. Forty-second Street, New York City.

1890–91, Designing with Tiffany Glass and Decorating Co., New York. 1891 to date, member of above firm.

ANSBACHER, LOUIS ADOLPH, PH. B., ... 1892.
A. B. Ansbacher & Co., 4 Murray St., New York City and Arverne L. I., N. Y.

ANTHON, ARCHIBALD, E. E. (Associate), . . . 1892.
13 West 35th St., New York City.

APPLEBY, W. R., A. B. (Associate), ... 1887.
Professor of Mining and Metallurgy, School of Mining and Metallurgy, University of Minnesota, and 911 Fifth St., S. E., Minneapolis, Minnesota.

ATHA, HENRY GURNEY, PH. B., A. M. (Williams), . 1889.
756 High St., Newark, N. J.

AUSTEN, PETER TOWNSEND, PH. B., PH. D., . . 1872.
Polytechnic Institute, 99 Livingston St., and 876 President St., Brooklyn, N. Y.

1878–80, Assistant Professor of Analytical Chemistry, Rutgers College. 1890–1889, Professor of General and Applied Chemistry, Rutgers College. 1891, Superintendent Manufactories of W. J. Matheson & Co., limited, Ravenswood, N. Y. 1892, General Manager, Ledoux Chemical Laboratory. 1893, Professor of Chemistry, Polytechnic Institute, Brooklyn, N. Y.

AUSTIN, THOMAS SEPTIMUS, E. M., ... 1876.
Chihuahua Mining Co., Chihuahua, Mexico.

1877–78, in Cuba as Chemist. 1879–80, Assayer Germania Smelting Co. 1880–90, Superintendent Rio Grande Smelting Co., Socorro, N. M.

B.

BAKER, GEORGE LEWIS, PH. B., ... 1888.
Address unknown.

BALCH, SAMUEL WEED, E. M., ... 1883.

Box 333, Yonkers, N. Y., and 41 Wall Street, New York City.

1863-84, Ottis Elevator Co. 1884-86, Mowing Machines. 1886-89, Garvin Machine Co., Tools and Special Machinery. 1889 to date, General consulting practice as Mechanical Expert and Patent Attorney. Specialty, Difficult Mechanical Problems.

BALDWIN, WILLIAM M., PH. B. (Life Member) . . 1884.

55 Beekman Street, New York City, and Garden City, Queens Co., N. Y.

Since 1885, Chemist for the New York Dye Wood Extract and Chemical Co. Since 1888, Vice-President of the above corporation, and at present having charge of their manufacturing department.

BANKS, JOHN HENRY, E. M., PH. D., ... 1883.

104 John Street, New York City, and Boonton, N. J.

1883-85, Chemist with Ledoux & Ricketts, New York. 1885-91, Private Assistant to Prof. Ricketts, School of Minds, New York, in general analytical, metallurgical and mining engineering work. 1889-91, Hon. Fellow in Assaying, School of Mines. 1894 to date, in partnership with Prof. Ricketts, at above address, in general chemical, metallurgical and Mining engineering work, with Ore testing Works, at Waverly, New Jersey, for determining treatment of ores and examination of processes.

BARNARD, EDWARD CHESTER, E. M., ... 1884.

U. S. Geological Survey, Washington, D. C.

Assistant Topographer and at present Topographer in the United States Geological Survey, 1884-91. Have been engaged in mapping in Virginia, West Virginia and the mountains of East Kentucky. 1893, Mapping Northern New York.

BARNETT, L. H., E. M., ... 1894.

289 Columbus Avenue, New York City.

BARRATT, EDGAR GRANT, C. E., ... 1884.

1123 The Rookery, Chicago, Ill., and Kenilworth, Ill.

1884-88, Engineer for The Exhaust Ventilator Co. 1888 to date, President and Proprieter of the Exhaust Ventilator Co. 1891 to date, President and General Manager of the Variety Manufacturing Company. Fill the above positions at present and am consulting Ventilating and Heating Engineer.

BARUS, CARL, PH. D. (Associate), ... 1877.

Brown University, Providence, R. I.

BAXTER, GEORGE STRONG, A. B., E. M. . . . 1868.

17 Broad Street, New York City.

1878-79, Civil and Mining Engineer. 1880, Cashier N. P. R. R. 1890, Treasurer N. P. R. R.

BAYLES, FREDERICK P., E. M. . . . . 1895.
Chemist Colorado Fuel & Iron Co., Sopris, Colo., and 408 Main Street, Orange, N. J.
Chemist and Assayer for the Sonora Copper, Co., Sonora, Old Mexico.

BEARD, JAMES THOM., E. M., C. E., ... 1877.
304 Webster Avenue, Scranton, Pa.
1879-80, Assistant Engineer, New York and Brooklyn Bridge. 1880-82, Assistant Engineer, C. B. and Q. R.R. 1882-83, Superintendent Smoko Hollow Mine, Avery, Ia. 1884-85, Assistant U. S. Dept. Min. Surveyor, Aspen, Colo. 1885-91, Engineer, Whitebreast Fuel Co., Ottumwa, Ia. 1891-92, Manager Miller Creek Land and Lime Co., Aspen, Colo. 1892-93, Secretary and Treasurer, Eldon Coal and Mining Co., Ottumwa, Ia. 1893 to date, Iowa Mining Exchange, Ottumwa, Ia. 1892-94, Wrote Beards *Ventilation of Mines*, published by John Wiley & Sons, New York City.

BECHSTEIN, CHAS. A. . . . . 1888.
405 West End Avenue, New York City.

BEEBE, ALFRED L. PH. B., ... 1880.
Health Department, Criminal Court Building, Centre Street, New York City and 44 Sanford Avenue. Flushing, L. I.
1880-87, inclusive, Private Assistant to Prof. Ricketts, School of Mines, New York, in General analytical work, especially Mineral Analyses. Also Assistant in Assaying and Fellow in Chemistry, in 1881-87, inclusive. 1888-92, Assistant Chemist, New York Health Department. Since September, 1892, Bacterologist, New York Health Department.

BEHRMAN, GEORGE WILLIAM, C. E., ... 1883.
201 Ross Street, Brooklyn, N. Y.
November, 1893, to January, 1894, Transitman and Draughtsman, with the Raub Locomotive Works and Land Improvement Company.

BELLINGER, HIRAM PAULDING, C. E., ... 1887.
Solvay Process Company and 1721 W. Genesee Street, Syracuse, N. Y.

BEMIS, FREDERICK POMEROY, A. B., E. M., . . 1885.
109 West 3d Street, Davenport, Iowa.

BENEDICT, WILLIAM DE LIESSELINE, E. M., . . 1874.
Welles Building, No. 18 Broadway, Rooms 617 and 618, New York City, and 282 Vanderbilt Avenue, Brooklyn, N. Y.
1878-80, Assistant Superintendent and Superintendent, Revere Concentrating Co., Utah. 1880-81, Assistant Superintendent, Germania Smelting & Refining Co., Utah. In 1882, opened an office in New York City, as Consulting Mining Engineer and Metallurgist, and have since been engaged in examining and reporting on Mines in the United States, Ontario, Quebec, British Columbia, Mexico and England.

BENOLIEL, SOL. D., E. E., ... 1896.
Cons. Elec. Eng., 1327 Broadway and 120 W. 35th Street, New York City.

BENJAMIN, MARCUS, PH. B., A. M. (Lafayette 1888) 1878, PH. D. (Univ. Nashville, 1889) (Life Member).
Editor, U. S. National Museum, Washington, D. C.

1878-82, with E. B. Benjamin, dealer in Chemical Apparatus. 1882, Editor *American Pharmacist*. 1883, Editor *Weekly Drug News*. May, 1883, to June, 1885, Chemist, U. S. Laboratory, New York. 1884-86, Lecturer on Chemistry, N. Y. Woman's Medical College and Hospital for Women. 1885, Sanitary Engineer, N. Y. Board of Health. 1886-89, Editorial Staff, Appleton's *Cyclopaedia of American Biography*. 1890, Editorial Staff, *Engineering and Mining Journal*. 1891-94, Editorial Staff in charge of Chemistry, *Standard Dictionary*. 1894-95, Editorial work for D. Appleton & Co. 1895, Editorial Staff, *Johnson's Universal Cyclopædia*, New York. 1895-96, at the Smithsonian Institution, and since April, 1896, Editor U. S. National Museum, Washington, D. C. At various times on editorial staffs, of *Scientific American*, 1883-89; *Independant Oil Journal*, 1886; and on technical subjects in *New York Daily News*, 1886-95; *New York Star*, 1890-91; and *Pharmaceutical Record*, 1891; also of *Appleton's Annual Cyclopædia* since 1883. Other work includes translation of Berthelot's lectures on "Explosive Materials" (New York, 1883); authorship of Druggist's Circular, Prize Essay on "Disinfectants," 1885; authorship of chapters on *Mineral Paints* in "Mineral Resources of the United States," for years 1884-86, and other non-technical works. Organized the Corresponding Chapter of Chemistry of the Agassiz Association in 1892, and its President till 1896. Life fellow of the London Chemical Society, and of the American Association for the Advancement of Science; Member of Society of Chemical Industry, London, and of American Chemical Society, Member of International Jury of Awards, World's Fair, Chicago, 1893.

BERRY, WILTON GUERNSEY, PH. B., ... 1886.
Health Department, New Criminal Courts Building, New York City.

1886-89, Universities of Berlin and Heidelberg and General Chemical Research, 1889 to date, Assistant Chemist, New York Health Department.

BERRY GEORGE, C. E., ... 1888.
78 Morton Street, Brooklyn, N. Y.

BETTS, ROMEO T., C. E., ... 1890.
191 Halsey Street, Brooklyn, N. Y.

BIEN, JOSEPH RUDOLPH, E. M., ... 1887.
140-142 6th Avenue, and 321 West 57th Street, New York City, N. Y.

1887-88, Topographer, U.S. Geological Survey, Survey of Geyser Basins, Yellowstone National Park. 1888-90, Practice as Civil and Mining Engineer, firm of Vermeule & Bien, New York City. 1890-91, Practice as Civil and Topographical Engineer alone, New York City. At present, Secretary Julius Bien & Co., Lithographers, Engravers and Geographical Publishers.

BINION, JOSHUA, B. S., ... 1895.
C. R. R. of N. J., Jersey City, N. J., and care 232 Madison Street, New York City.

Summer of 1893. Volunteer Assistant on New York Speedway. Summer of 1895, Assistant at Summer School of Surveying. Columbia University. October 9, 1895, with C. R. R., of N. J. in charge of Bound Brook depression.

BLACK, ADOLPH, C. E., ... 1894.
1434 Lexington Ave., New York City.

July 1, 1894, to July 1, 1896, Assistant in Department of Civil Engineering, under Professor Burr, School of Mines, Instructor Summer School of Surveying, summers of 1893, 1894 and 1895. Instructor Summer School of Astronomy and Geodesy, summer 1895, State Inspector N. Y. State Tenement House Commission 1894. Instructor in Mechanical Drawing, Y. M. C. A., 23d Street Branch, 1894–95, and 1895–96. Sanitary Engineer for New York Department Public Parks, 1896. Designing Engineer for New York Department Public Works, 1896.

BLAKE, EDWIN MORTIMER, E. M., PH. D. (1893). . 1890.
Instructor in Mathematics, Purdue University, Lafayette, Ind., also 230 Washington Ave., Brooklyn, N. Y.

BLEECKER, C. P., ... 1881.
446 Avenue E. Bayonne, N. J.

BLOSSOM, FRANCIS, C. E., ... 1891.
Westinghouse Church, Kerr & Co., 26 Cortlandt Street, New York City, and 440 Henry Street, Brooklyn, N. Y.

1891–92, Engineer with C. W. Hunt Co. 1892, Assistant Engineer Equity Gas Works Construction Company. 1893, as above.

BLYDENBURGH, CHARLES EDWARD, A. B., A. M., E. M., 1878.
Mining Expert and Prospector, Box 180, Rawlings, Wyoming.

BODELSEN, OSCAR, E. M., ... 1884.
Cons. Gas Co., Foot West 44th Street New York City, and Pocantico Hills, N. Y.

BŒCKLIN, WERNER, JR., C. E., , ... 1891.
Chief Engineer's Office, Penna. Company, Pittsburgh, Pa.

January to May, 1893, ran level on preliminary (150 miles), H. &. E. Extension, C. O. & S. W. Railway, in charge of all profiles and estimates undes Chief Engineer. 1894, Inspector for Massachusetts Highway Commission on State Highway. Assistant Engineer in charge of erection of Stone Crushing Plant at Rock Hill, N. J., 1895.

BOGERT, MARSTON T., PH. B., A. B., ... 1894.
School of Mines, Columbia University, and 259 Broadway, Flushing, Queens County, L. I.

Awarded University Fellowship in Chemistry for 1895, but resigned to accept position of assistant in Organic Chemistry.

BOOK, DWIGHT DANA, C. E., E. E. (1892), . . 1890.
159 Washington Park, Brooklyn, N. Y.

BOOKMAN, S. (Associate) PH. D., M. A. . . . 1891.
9 East 62nd Street, New York City.

BOORÆM, ROBERT ELMER, E. M. (Life Member), . 1888.
2 East 15th Street, New York City.

1879, Assayer, general work in Leadville, Colorado. 1880–87, Assistant Superintendent, afterward manager, Evening Star Mining Co., Morning Star Consolidated Mining Co. and others at Leadville, Colorado, Lead-silver Mines. Also in charge Farwall Con. M. Co., Gold Mines at Independence, Colorado. 1887–90, General Manager Blue Bird Mining Co., Ltd., Butte, Montana, Operating 90-Stamp Mill, Dry Crushing, Chloridizing, Amalgamating Process. 1891, General Consulting Mining Engineer and Consulting Director in Gold, Silver and Lead-Mining Companies, of which a Specialty is made. Also Mine Operator and owner, Silver Mines at Aspen, Colorado.

BOYD, RICHARD CHARLES, PH. B., A. M. (1892), . 1891.
44 W. 88th Street., New York City.

BRADLEY, STEPHEN ROWE, JR., PH. B., . . . 1890.
Orangeburg and Nyack, N. Y.

July, 1891 to 1894, Secretary and Treasurer Union Electric Co. January, 1894. Secretary and Treasurer The Arlington Manufacturing Co., New York City.

BRASCHI, VICTOR MANUEL, PH. B., E. M., C. E., . 1881.
Apartado 830, City of Mexico, Mex.

June, 1884, to October, 1884, Inspector of New York Tenement House Commission. October, 1884, to May, 1885, Interpreter and Secretary to Governor Chilian, Commissioner to Visit and Report on American Mining and Smelting. May, 1885, to October, 1885, Employed by Rend-Rock Powder Co. in Flood Rock Explosion Work. October, 1885, to January, 1889, Assistant Consulting Engineer and in Charge Foreign Business, Rand Drill Co. January, February, March, 1889, Reporting on Mines in Mexico for above Co., and for three years, from April, 1890, to April, 1893, engaged in introducing Rank Rock Drilling Machinery in Mexican Mines. In April, 1893, arranged to open a general Mining Machinery and Supply business, in the City of Mexico, in which I am at present engaged.

BRERETON, THOMAS J. A. B., 1879, C. E., . . . 1883.
Engineer Cumberland Valley Railroad and 5th Avenue, Chambersburg, Pa.

1979, Rodman on Location of Redstone Br. P. R. R. 1880 and 1880 (Summers) on New York State Geodetic Survey of Adirondacks. 1883–85, Leveller P. R. R. Clearfield Co. Surveys and Construction. On Corps of Engr. M. of W. P. R. 1888–89, Assistant Supervisor, P. R. R. 1890–92, Supervisor Tyrone Div., P. R. R. 1893, Engineer Cumberland Valley Railway.

BREWSTER, HENRY DRAPES (Associate), . . . 1883.
Care Brewster & Co., 49th Street and Broadway, New York City.

BRINLEY, JOHN ROWLETT, C. E. . . . . 1884.
Morristown, N. J.

1884–88, Department of Public Works, New York City. 1888 to date, Civil and Sanitary Engineer.

BRITTON, NATHANIEL LORD, E. M., PH. D., . . 1879.
41 East 49th Street, New York City.

Assistant of Geology, School of Mines, 1879–1887. Instructor in Botany, Columbia University, 1887–1890. Adjunct Professor of Botany, Columbia University, 1890–1891. Assistant Geological Survey of New Jersey, 1880–1887. Botanist, Geological Survey of New Jersey, 1881, 1890. Field Assistant, U. S. Geological Survey, 1882. Professor of Botany, 1891. Specialty—Systematic Botany. Director-in-Chief New York Botanic Garden.

BROSNAN, FRANCIS XAVIER, C. E. . . . . 1891.
146 W. 74th Street, New York City.

BROWN, FRANCIS G., E. M., ... 1867.
Merchant, 15 Whitehall Street and 462 Lexington Avenue, New York City.

BROWNING, JOHN H. BROWER, M. D. (Associate), . 1880.
Smithstown, L. I., N. Y.

College of Physicians and Surgeons of City of New York, in year 1882. Afterwards Assistant Physician, New York City Insane Asylum, Ward's Island, 1882–83. House Physician and Surgeon to St. Francis Hospital, 1883–85. At date, Member County Medical Society of New York, Member Physicians' Mutual Aid Association, Fellow American Geographical Society, and Assistant to Chair in Surgery, New York Polyclinic, Medical Examiner for Presbyterian Board of Foreign Missions, General Practitioner of Medicine and Surgery.

BROWN, ROBERT GILMAN, E. M., ... 1889.
Standard Consolidated Mining Co, Bodie, Cal.

BRUGMAN, WILLIAM FREDERIC, PH. B., ... 1880.
One Hundred and Forty-fourth Street and Southern Boulevard, New York City and Los Angeles, Cal.

BRYCE, WILLIAM, JR., PH. B., ... 1884.
40 W. 54th Street, New York City.

BUCKLEY, CHARLES RAMSAY, A. B., A. M., E. M., . 1877.
29 Broadway, New York City.

BURDEN, HENRY 2d, A. B., PH. B., ... 1892.
Cazenovia, N. Y.

BURNS, ABRAHAM LINCOLN, E. M., ... 1887.
Member of Firm, Trask Burns & Co., 99 Ceder St., New York City.

Since November, 1887, with Messrs. Jabez Burns & Sons (Millwrights and Machinists, and Manufacturers of Patented Machines for Treating Coffee and

Spices). Since July, 1890, in above firm. Professional work has been general shop draughting and machine design, and arranging machines and power transmission in coffee establishments.

BURNS, ELMER Z., E. M., ... 1887.
Niagara Falls, N. Y.

1887–88, Engineer and Chemist for the Pittsburgh and Lake Angeline Iron Co. 1889–90, Assistant Electrician for the United States Electric Light Company. 1890–91, Assistant Electrician for the Mather Electric Company. 1891–93, City Engineer of Niagara Falls, and Consulting Engineer for the Lewiston and Youngstown R. R. Company, for the North Tonawanda Street Railroad Company, and for the Niagara Falls and Suspension Bridge Railroad Company.

BURRITT, WILMOT WOODWARD, PH. B., . . . 1884.
Chemist, Englewood, N. J.

BUSH, EDWARD RENSHAW, E. M., ... 1881.
Mining Engineer, with Ricketts and Banks, 104 John St., New York City.

BUTLER, NATHANIEL, E. M., ... 1880.
51 Cedar St., Room 7, New York City, and Glen Ridge, Bloomfield, Essex Co., N. J.

1880–82, U. S. Harbor Improvement and Railroad Engineering. 1882–94, Barlow's Insurance Surveys as Surveyor, Superintendent and Executive.

BUTLER, WILLIAM CURTIS, MET. E., ... 1887.
Everett, Washington, and 165 Hamilton Ave., Paterson, N. J.

1887–89, Assayer, El Paso Smelting Co., El Paso, Texas. 1889–90, Chemist, afterward Assistant Superintendent, Arkansas Valley Smelting Co., Leadville, Colo. 1890, Chemist, now Assistant Manager, Aurora Iron Mining Co., Superior Mining Co., Comet Mining Co., Palone Iron Mining Co., Penokee and Gogebic Development Co. (Operating Colby and Tilden Mines). Also in charge Ironwood Electric Co., Gobebic Electric Co. 1892, Superintendent Monte Cristo Mining Co., Seattle, Washington. 1893, Manager Puget Sound Reduction Co. 1894, President and Treasurer Puget Sound Reduction Co.

BUTLER, WILLARD PARKER, E. M., LL. B. (Life Member), 1878.
Counsel in Patent Causes, 59 Wall St., and 143 East 36th St., New York City.

C

CADY, LINUS BERTRAM, E. M., C. E., ... 1877.
327 Fifth Ave., New York City.

CALMAN, ALBERT, PH. B., PH. D., ... 1882.
7 W. 75th Street, New York City.

CANFIELD, AUGUSTUS CASS., E. M., ... 1877.

CANFIELD, FREDERICK A., A. B., A. M., E. M., . . 1873.
Mining Engineer, Dover, N. J.

CARSON, JAMES PETTIGRU, E. M., ... 1868.
16 Exchange Place, New York City, and Dean Hill Oaky, P. O. S. Ca.

CARTER, B. P., E. M., ... 1895.
Crown Deep Mine, Ltd., P. O. Box 771, Johannesburg, S. A. R.
December, 1895, to date, Surveyor and Assayer of the Crown Deep, Ltd.

CASAMAJOR, GEORGE H., C. E., ... 1892.
141 East 25th Street, New York City, and 372 Greene Ave., Brooklyn, N. Y.

1892–May, 1893, with the *Railroad Gazette*, N. Y. May–September, 1893, with C. B. Brush, Hoboken, N. J. as Transitman, Levelman, etc. October, 1893–January, 1896, with the East River Gas Company, N. Y. February–May, 1896, Engineer Inspector D. P. W., N. Y. May, 1866, became a partner in the Bacheller Newspaper Syndicate, occupied in literary and editorial work.

CASEY, EDWARD PEARCE, C. E., PH. B. (1888), . . 1886.
Architect, 171 Broadway and The Alpine, 55 West Thirty-third St., New York City.

With McKim, Meade & White, Architects, New York City, until January, 1890. Abroad, and Student in L'Ecolo National des Beaux Arts, Paris, from February, 1890, until September, 1893. Five mentions in Architecture, and a medal in Modeling. At present Architecture, 171 Broadway, New York City.

CAULDWELL, JOHN BRITTON, C. E., ... 1877,
Century Club, 7 West Forty-third St., New York City.

CHANNING, JOHN PARKE, E. M., ... 1883.
34 Park Place, New York City.

1893, Chemist Hudson River, O. and I. Co. 1884, with S. E. Cleaves & Son, Manufacturers of Mining Machinery, Houghton, Mich. 1884–95, Assistant Mining Engineer Tamarack Mine, Calumet, Mich., Dep. Comm. Mineral Statistics, Michigan. 1885–86, Superintendent Honduras Land and Navigation Co. 1886–87, Exploring for iron on the Gogebic Range, and Mining Engineer for Milwaukee, L. S. and Western Railway, Superintendent Iron Belt Mine. 1887–90, Inspector of Mines, Gogebic Co., Mich. 1790–92, Superintendent East New York Iron Co., Ishpeming, Mich. 1892–1893, Superintendent Iron Exploration Co., C. M. and St. P. Railway. Assistant to General Manager Calumet and Hecla Mining Company, 1894, Consulting Work, 1894, to date.

CHESTER, ALBERT HUNTINGTON, A. M., E. M., SC. D., PH.D., 1868.
Professor of Chemistry and Mineralogy, Rutgers College, and 35 College Avenue, New Brunswick, N. J.

Professor of Chemistry at Hamilton College from 1870 and Mineralogy from 1878 to 1891. Conducted the Analytical Laboratory there from 1871. Chemist New York State Board of Health, 1882. Examined and reported on Mines of iron, gold, silver, lead and zinc, in Michigan, Minnesota, Ontario, Arkansas, Colarado, Utah, Nevada, California and Nova Scotia. Analytical work has been largely in two lines, viz., for iron-blast furnaces and of paints and varnishes.

Field work has been, a great part of it, in the iron mines of Minnesota and the gold mines of Colorado. Now engaged in chemical work for the State Geological Survey of New Jersey.

CHURCH, ELIHU DWIGHT JR., E. M., ... 1887.
Church and Co., Trenton, Wayne Co., Mich.

1887–88, Fellow Qualitative Analysis School of Mines. 1888–89, Assistant Superintendent of Lead Mine and Concentraring Works. 1889–91, with Church & Co., in charge of experimental plant.

CHURCH, JOHN ADAMS, A. M., E. M., PH. D., . . 1867.
Corn Exchange Building, 11 William Street, and 1350 Madison Avenue, New York City, Cable address Scotist, N. Y.

CLARK, A. J., E. M., ... 1896.
Tenn. Coal, Iron and R. R. Co., Blockton, Ala., and care of B. S. Clark, Box 158 New York City.

CLARK, DIEGO LOMBILLO, C. E., ... 1890.
Cardenas, Cuba.

CLARK, EDMUND (Associate), ... 1892.
Health Dept., Criminal Court Bldg., Centre and Franklin Streets, and 148 East 34th Street, New York City.

From August, 1892, to August, 1895, Assistant Chemist, Homestead Steel Works, Carnegie Steel Co., Pittsburg, Pa. Since August 1, 1895, Assistant Chemist, Board of Health, New York City.

CLARK, EDWIN PERRY, E. M., ... 1880.
Title Guarantee and Trust Co., 26 Court Street, and 464 Second Street, Brooklyn, N. Y.

1880–83, Engineer and Surveyor for Silver-Cord Combination, and Robert E. Leo Mining Companies, Leadville, Colo. 1883–84, Medical student. 1884 to date, Assistant Superintendent and afterwards Superintendent Title Guarantee and Trust Company, 55 Liberty Street, New York, and 26 Court Street, Brooklyn. In charge of construction and maintenance of locality-indexes of Real Estate Records of New York, Kings and Westchester counties, N. Y.

CLARK, FRANKLIN SINCLAIR, E. M., PH. D., . . . 1885.
Carolina Oil and Creosote Co., Wilmington, N. C., and 527 Madison Avenue, N. Y. City.

1885–87, Chemist to Fernoline Chemical Co., Charleston, S. C. 1887 to date, Proprietor of Southern Chemical Works and consulting chemist for the Carolina Oil and Creosote Co., Wilmington, N. C. Specialty, Distillation of Wood and refining products and creosoting wood.

CLARK, GEORGE HALLETT, C. E., ... 1893.
59 E. Sixty-seventh Street, New York City.

1893–94, Transitman Metropolitan Traction Co., Lexington Ave. Cable Construction. Assistant Engineer in charge construction Lexington Avenue Cable Road. Assistant Engineer D. D. I., from June 1, 1896, to date.

CLARK, WILLIAM C., M. E., ... 1892.
Sterling I. and Ry. Co., Sterlington, Rockland Co., N. Y.

COKEFAIR, FRANCIS A., C. E., ... 1894.
66 Broadway, New York City, and 119 Cresent Ave., Plainfield, N. J.

COLBY, ALBERT LADD, PH. B., ... 1881.
The Bethlehem Iron Co., South Bethlehem, Pa.

1881–83, Assistant to Prof. C. F. Chandler on New York State Board of Health Bureau of Chemical Analysts. 1883–86, Instructor in Quantitative Analysis and Chemical Philosophy in the Lehigh University, South Bethlehem, Pa. 1886–92, Head Chemist of the Bethlehem Iron Co. 1893, to date, Metallurgical Engineer same Company, South Bethlehem, Pa. Specialty, Metallurgy of Iron and Steel.

COLBY, CHARLES EDWARDS, E. M., C. E., . . . 1877.
Adj. Professor Organic Chemistry, Columbia University School of Mines, New York City.

COLE, HAROLD MORRIS, E. M., C. E., ... 1887.
Care United S. and R. Co., East Helena, and 1045 N. Warren St., Helena, Montana.

COLTON, CHARLES ADAMS, E. M., ... 1873.
363–371 High Street, and 57 Broad Street, Newark, N. J.

1873–82, Assistant in Mineralogy, School of Mines, Columbia College, New York. 1882–84, Professor of Chemistry and Mineralogy, Rose Polytechnic Institute, Terre Haute, Indiana. 1884 to date, Director and Instructor in Chemistry and Physics, Newark Technical School.

CONANT, HENRY DUNNING, E. M., ... 1886.
Address unknown.

1886–88, Assistant Engineer Tamarack and Osceola Mines, Lake Superior, and H. and C. R. R. 1888–89, Assistant Engineer on Preliminary of Northern Michigan Railroad. 1889, Assistant in Chief Engineer's Office, Buffalo and Geneva Railway. 1889-91, Assistant and Resident Engineer Norfolk and Western Railroad, in charge of Preliminary Location and Construction. 1891, Engineer Coeburn Land and Improvement Co. 1893, Assistant Engineer N. Y., N. H. & H. Ry. 1894, Assistant Engineer Plaza de Oro Mining Co., Ecuador, S. A.

CONGDON, ERNEST ARNOLD, PH. B., F. C. S., . . 1887.
Professor of Chemistry, Drexel Institute Arts, Science and Industry, and 1336 Spruce Street, Philadelphia, Pa., or care H. M. Congdon, 18 Broadway, New York City.

1887–89, Chemist to Champlain Fibre Co., Willsborough, New York. 1889, Studied at the University of Berlin, Summer Semester. 1889 to date, Instructor in Qualitative Analysis and Assaying at the Lehigh University. 1891, Professor of Chemistry in the Drexel Institute of Arts, Sciences and Industries, Philadelphia, Pa.

COOPER, WILLIAM HAMILTON, PH. B. (LIFE MEMBER), . 1882.
Address unknown.

CORCORAN, JOHN THOMAS, E. M., S. E., . . . 1884.
131 Smith Street, Brooklyn, N. Y.

CORNWALL, HENRY BEDINGER, A. B., A. M., E. M., PH. D., 1867.
Professor Analytical Chemistry and Mineralogy, College of New Jersey, and 51 Nassau St., Princeton, N. J.

CORNWALL, HARRY CLAY, E. M., ... 1879.
Commonwealth Insurance Co., Nassau Street, New York City.

COX, JENNINGS STOCKTON, JR., MET. ENG., . . . 1887.
902 Lewis Block, Pittsburgh, Pa.

1887, Government Survey for Canal between Harlem and Hudson River. 1888–1889, Homestead Steel Works, Draughtsman and afterward Assistant Master Mechanic. 1890, Inspected construction of Steamer "Sezurania" and "Vigilancia" for the U. S. and B. M. S. S. Co., at Roach's Shipyard, Chester, Pa. 1891, Reporter for same Company on Engineering matters along the Brazil coast. 1892, with same Company in New York. 1892, Assistant Superintendent Aurora Iron-Mining Company, Ironwood, Michigan. 1893, Assistant Superintendent Monte Cristo Mining Co., Pride of the Mountain Mining Co., Rainy Mining Co., and United Concentration Company. 1894, Professional work in New York and Cuba. 1895, Agent Crocker-Wheeler Electric Co., Pittsburg, Pa.

COYKENDALL, EDWARD, C. E., ... 1895.
Rondout, N. Y.

CRAMER, STUART W., E. M. (Associate), . . . 1889.
Manager The D. A. Tomkins Co., Charlotte, N. C.

Graduate of United States Naval Academy; resigned from the United States Navy, September, 1888. Graduate student at School of Mines, 1888–89. Assayer in charge of the United States Assay Office, Charlotte, N. C., 1889–93. Special agent for collection of statistics on gold and silver for the Southern States, 1890. March 10, 1893, to present time, Engineer and Chemist for the D. A. Tompkins Company, General Engineers and Contractors, of Charlotte, N. C. Special correspondent of *Engineering and Mining Journal*. Specialty: Westinghouse system of electric lighting and transmission of power.

CROCKER, FRANCIS BACON, E. M., ... 1882.
Professor Electrical Engineering, Columbia University School of Mines, and 110 West 39th Street, New York City.

1882–86, Electrical Engineer and Inventor. 1886–87, Vice-President and Electrician of "C. and C." Electric Motor Co. 1887–89, Vice-President and Electrician Crocker-Wheeler Electric Motor Co. 1889–92, Instructor in Electrical Engineering, School of Mines, Columbia University. 1892, Adj. Professor. 1893, Professor.

CUSHMAN, ALEXANDER RAMSEY, PH. B., PH. D., . . 1878.
Assistant Analytical Chemistry, Columbia University School of Mines, and 128 E. Sixteenth Street, New York City.

1878–80, Post Graduate study at the School of Mines, for degree of Ph. D. 1880–82, in Colorado, visiting mines and smelters. 1882–90, engaged in pursuing

chemical studies and lecturing on geology. 1890 to date, Assistant Instructor in Qualitative Laboratory at the School of Mines, Columbia University.

D.

DARWIN, HARRY GILBERT, C. E., ... 1887.

Room 23, 160 Broadway, New York City, and Glen Ridge, N. J.

June, 1887, to October, 1887, Rodman and Leveller on Railroad field work in New York State. October, 1887, to May, 1888, Draughtsman Strong Locomotive Co., New York City. August, 1888, to date, Assistant Engineer and Acting Superintendent Safety Car Heating and Lighting Co., New York City. Erection of special gas works, and equipment of railroad cars, etc. P. Asst. Ang. S. C. H. L. Co.

DAVIS, CHARLES HENRY, C. E., ... 1887.

Room 306 Fidelity and Casualty Building, 99 Cedar Street, New York City.

Expert Course and Thompson-Houston Electric Co., Lynn, Mass., summer 1887. Agent, Lawyer Mann Electric Co., winter 1887–88. Supt. selling and construction New York office S. M. Electric Co., summer and winter 1888. Agent Westinghouse Electric Company, winter 1889. Consulting and Supervising Electrical Engineer from May, 1889, to date.

DAVIS, JOHN WOODBRIDGE, C. E., PH. D., . . . 1878.

Principal Woodbridge School, 417 Madison Avenue and 25 West 119th Street, New York City.

DEGHUÉE, JOSEPH ALBERT, PH. B., A. M., (1892) PH. D., (1893) . . . . . 1890.

Health Dept., New York City, and 247 Harrison St., Brooklyn, N. Y.

Assistant Demonstrator in Physics and Chemistry, College of Physics and Surgery, to March, 1896. March, 1896, to date, Assistant to Chemist New York City Health Department.

DELAFIED, AUGUSTUS FLOYD, PH. D. (Associate), . . 1869.

University Club, New York City.

DELUZE, LOUIS PHILIPPE, C. E., ... 1879.

DeLuze & Emmett, Engineers and Surveyors, New Rochelle, N. Y.

DENTON, FREDERICK WARNER, C. E., ... 1884.

University of Minn. and 1100 5th St., Minneapolis, Minn.

1889–90, Fellow in Engineering, School of Mines. 1890–94, Professor of Mining and Civil Engineering, Michigan Mining School, and in general practice of engineering. 1894 to date, Mining Engineer Minnesota Iron Co. Secretary of the Lake Superior Mining Institute since its organization in 1893.

DERLETH, CHAS. J., B. S., C. E., ... 1896.

674 East 135th St., New York City.

Assistant in Civil Engineering, Columbia University.

DEVEREUX, WALTER BOURCHIER, A. B., A. M., E. M., . 1878.
Address unknown.

DOBBINS, MAX, E. M., ... 1895.
Care of Lehigh Valley Coal Co., Engineering Department, and 14 Wright St., Wilkesbarre, Pa.

DODGE, FRANK DESPARD, PH. B., PH. D., . . . 1888.
Dodge & Olcott, 137 Water St., and 111 Montague St., Brooklyn, N. Y.

From October, 1891, to date, Chemist, with Dodge & Olcott, manufacturers of essential oils, etc. 1888-90, Fellow in Chemistry, Assistant in Organic Laboratory School of Mines. 1890-91 (studying in Germany).

DOLAN, CHARLES FRANCIS, C. E., ... 1892.
111 East 129th St., New York City.

1892-93, United States Inspector of Dredging Operations, Harlem Ship Canal and Newtown Creek. 1893 to date, with Department of Street Improvements, New York City. 1894, with U. S. Engineers on New York Harbor Improvements.

DONNELL, HARRY ELLINGWOOD, PH. B., . . . 1887.
Address unknown.

DOUGLAS, JOHN SHEAFE, C. E., ... 1890.
Chaplin-Douglass Electric Co. Mnfgs. Agents, 136 Liberty St., and 72½ Irving Place, New York City.

1890, Course Electrical Engineering, Columbia College. 1891, Crocker-Wheeler Electric Motor Company, and now Assistant Engineer Western Electric Company in Lighting Department. 1893, Superintendent of Union Elect. Co.'s Exhibit at World's Columbian Exposition, Chicago. 1895, Secretary and Treasurer Chapin-Douglas Elec. Co.

DOUGLASS, EDWARD MOREHOUSE, C. E., . . . 1881.
Topographer U. S. Geol. Survey, and Takoma Park, Washington, D. C.

DOW, ALLAN WADE, PH. B. (Life Member), . . 1888.
Office of the Engineer Commission, District of Coulmbia, Washington, D. C.

1888-89, Honorary Fellow Quant. Laboratory, School of Mines. 1889, Chemist at Tilly Foster Mine, New York. 1889-91, Assistant Chemist of The Barber Asphalt Paving Co. 1894, District Chemist, Inspector Asphalt Cement and Building Stone, District of Columbia.

DOWNS, WILLIAM FLETCHER, E. M., ... 1882.
Joseph Dixon, Crucible Co., and 75 Fairview Ave., Jersey City, N. J.

With the Joseph Dixon Crucible Co. since graduation. From June, 1882, to September, 1882, at experimental work. From September, 1882, to October,

1884, in charge of lubricating department. From October, 1884, to present time Superintendent of crucible and other departments.

DRASEL, CHARLES, E. M., ... 1895.
56 Bowers St., Jersey City, N. J.

DRESSER, DANIEL LE ROY, C. E., ... 1889.
55 White Street, New York City and Oyster Bay, L. I., N. Y.

DRUMMOND, ISAAC WYMAN, E. M., PH. D., . . . 1878.
F. W. Devoe & Co., William and Fulton Sts., New York City.

DUFOURCQ, EDWARD LEONCE, E. M., ... 1892.
Oficiana Volcan, Sierra Mojada, Coahuila, Mexico.

1892–93, Assistant Superintendent Costa Rica Pacific Gold Mining Company, Punta Arenas, Costa Rica. Summer of 1893, Assistant in Mining, Columbia College and Transitman for J. F. Carey & Co., Brooklyn. November, 1893, Assistant Engineer, Mazapil Copper Company, Concepion del Oro, Zacatecas, Mexico, and Assistant Engineer Coahuila and Zacatecas Railroad. Fall of 1894, Engineer of International Mining Co., San Miguel de Mesquital, Mexico. 1895–96, Mining Department Kansas City Smelting and Refining Company, El Paso, Texas.

DUNHAM, EDWARD KELLOGG, PH. B., ... 1881.
338 East Twenty-sixth Street, New York City.

Professor of Pathology, Bacteriology and Hygiene in the Bellevue Hospital Medical College, New York City.

DURHAM, H. W., C. E., ... 1895.
U. S. Geological Survey, Washington, D. C., and 125 Brooklyn Avenue, Brooklyn, N. Y.

Draughtsman Rapid Transit Commission, June to December, 1895. Field Assistant U. S. Geological Survey, May, 1896, to date.

DUSENBERRY, WALTER LORTON, E. E., ... 1884.
220 Tenth Street, S. Brooklyn, N. Y.

1884–87, miscellaneous. U. S. Coast Survey. Mining in Mexico and the West. Survey of New Parks, Westchester County, etc. 1887–89, Inspector of Masonry and Transitman on New Croton Aqueduct. 1889–91, in charge of party and Assistant Engineer of Construction Department of Public Parks, New York City.

DUTCHER, BASIL H., PH. B., ... 1882.
525 Manhattan Avenue, New York City.

Summer of 1890, on Reconnaissance Survey in Idaho and Nevada, Biological Survey, U. S. Department of Agriculture. Summer of 1891, on Death Valley Survey, California, U. S. Department of Agriculture. Summer of 1892, Biological Survey, U. S. Department of Agriculture, in Kansas, Oklahoma, Texas, New Mexico. Winters, 1892–93 and 1893–94, Student College Physicians and Surgeons, Columbia University.

DWIGHT, ARTHUR SMITH, E. M., ... 1885.
Superintendent Colorado Smelting Co., Pueblo, Colorado.
1885, Assistant Assayer at works of The Colorado Smelting Company, Pueblo, Colorado. 1885 to 1888, Assistant Chemist and Chemist, except autumn of 1886, when examining and reporting on lead deposits of Cœur d'Alene region, Idaho Territory, and spring of 1889, when acting as Assistant Supt. Madonna Mine, Monarch, Colorado. 1889–90, Metallurgist, and up to date, General Supt. of the Colorado Smelting Co.

E.

EASTON, LANGDON CHEVES, C. E., ... 1884.
59 Flood Bldg. and 1906 Bush Street, San Francisco, Cal.
1885–88, Engineer Corps, Aqueduct Commission, New York City. 1889–96, Inspector and Assistant Engineer engaged in River and Harbor Improvement in California under direction of Corps of Engineers, U. S. A.

EASTWICK, GEORGE SPENCER, C. E., ... 1879.
Manager American Sugar Refining Co., 24 North Peters St., New Orleans, La., and 1425 Broadway, New York City.

EASTWICK, EDWARD PEERS, JR., PH. B., S. E., C. E. (1892), 1889.
Care of American Sugar Refining Company, New Orleans, La.

EBERHARDT, WILLIAM G., E. M., ... 1891.
450 W. Twenty-second St., New York City, and Oakland Place, Tremont, New York.
1891–93, General Engineering and Draughting, March, 1893, to May, 1894, Assistant Superintendent and Assayer Powhatan Land and Mining Co., Va. 1894–95, Assayer and Surveyor Mazapil Copper Co., Zacatecas, Mexico. 1896, Professional work in New York and New Jersey.

EDDIE, EDWARD CRITTENDEN, E. M., ... 1885.
Colorado Smelting Co., Pueblo, Colo.

EDWARDS, RICHARD MASON, E. M., ... 1886.
Red Jacket and Houghton, Mich.
1886–87, General Assay office at Houghton, Mich. 1888–89, Professor of Mining, Michigan Mining School, Houghton. 1890 to date, Mining Engineer for Tamarack, Tamarack, Jr., Osceola and Kearsarge Mining Cos., L. S. Mich.

EILERS, KARL EMRICH, E. M., ... 1889.
Mining Dept. Cons., Kansas City Smelting and Refining Co., El Paso, Texas, and 751 St. Mark's Ave., Brooklyn, N. Y.
1889–91, student and traveling in Europe. 1895–96, Assistant Superintendent Colorado Smelting Co., Pueblo, Col.

ELLIOTT, ARTHUR HENRY, PH. B., PH. D., . . . 1881.
4 Irving Place, New York City, and New Rochelle, N. Y.
Professor Chemistry and Physics, New York College of Pharmacy. Chemist to

Consolidated Gas Co. Editor Anthony's *Photographic Bulletin*. Author A. H. Elliott's Qualitative Chemical Analysis.

ELLIOTT, WILLIAM, PH. B., ... 1880.
56 Wall St., New York City.

EMANUEL, L. V., C. E., ... 1896.
122 E. 83d St., New York City.

ENGEL, LOUIS GEORGE, E. M., ... 1880.
Brooklyn Sugar Refinery, American Sugar Refinery Co., Kant Ave. and S. 2d St., and 238 Clermont Ave., Brooklyn, N. Y.

Three years, Tilly Foster Iron Mine (E. M.). Thirteen years, Brooklyn Sugar Refinery.

ENGELHARDT, EUGENE NICHOLAS, E. M., . . . 1885.
Selby, Contra Costa Co., Cal.

1886, Assayer, Chemist and Assistant Superintendent Pueblo Smelting and Refining Co. 1887 and 1888, Superintendent of the same company. 1889, Assistant Superintendent Anaconda Smelting Co. From 1890 and to present time, Assistant Superintendent Selby Smelting and Lead Co.

EVANS, I. N., C. E., ... 1895.
41 Dey St., New York City.

F.

FAHYS, GEORGE ERNEST, C. E., ... 1884.
38 Maiden Lane, New York City, and 285 DeKalb Ave., Brooklyn, N. Y.

Treasurer Prentiss Calendar Time Co.

FALK, DAVID BEAUREGARD, C. E., ... 1882.
Savannah, Ga.

FEARN, PERCY LE ROY, E. M., ... 1889.
18 Broadway, N. Y.

1889–90, Assayer and Surveyor, Trinidad Mine, Costa Rica. 1890–92, Superintendent, Trinidad Mine, Costa Rica. 1892–93, Consulting Mining Engineer Illinois Fluor Spar and Lead Co. 1893–94, Vice-President of above. 1894–96, engaged in examining and reporting on Mines in Western States and Mexico. 1896, entered firm of Olcott, Fearn & Peele, 18 Broadway, New York.

FERGUSON, WILLIAM CUSHMAN AUGUSTINE, PH. B., . 1887.
Nichols Chemical Co., Laurel Hill Chemical Works, Laurel Hill, N. Y., and 40 N. Parsons Ave., Flushing, L. I., N. Y.

Chief Chemist, Nichols Chemical Co., Laurel Hill, N. Y.

FERRER, CARLOS FERRER, C. E., ... 1883.
39 Broad Street, New York City.

After graduation for a few weeks on work at the School of Mines. Then under

Mr. W. E. Worthen, C.E., on some work for the Water Commissioners of the State of New Jersey. From March, 1884, to January, 1887, on the Engineering Corps of the Aqueduct Commissioners, New York City, as Assistant to Engineer of Construction; Leveler in charge of field work on Section "A;" reduced to Rodman in charge of same; promoted to Assistant Engineer; resigned in January, 1887, and have since been engaged in business for my own account at above address.

FERRIS, JUNIUS COLTON, E. M., ... 1883.
Carthage, Ill.

FEUCHTWANGER, HENRY, PH. B., ... 1832.
Room 19, 99 Franklin St., New York City.

FIALLOS, ENRIQUE CONSTANTINO, C. E., . . . 1883.
No. 27, Calle 10a, Tegucigalpa, Honduras, C. A., and Care Ernest Schernikow, P. O. Box 3540, New York City.

General practice in Engineering. Professor of Mathematics and Mineralogy in the University of Tegucigalpa. The most extensive practice has been as Government Surveyor of Lands and Mines.

FISHER, WILLARD E. M., ... 1888.
Agent Illinois Zinc Co., 115 Broadway, and 361 W. Fifty-sixth St., New York City.

Draughtsman to Parsons, C.E., New York City. Assistant to Superintendent Segovia Gold Mining Co., Nicaragua. Clerk, Office of Rich Hill Coal Mining Co., Rich Hill, Mo. Engineer and Mine Surveyor, Rich Hill Coal Mining Co., Rich Hill, Mo. Prospecting for coal, Southwest Missouri, along the line of Wichlaw & Western in the interest of the Missouri Pacific Railroad. Southern Sales Agent, Coal Cos., on the lines of Missouri Pacific Railway. President Tyler S. E. Railway of Texas.

FLOYD, FREDERICK WILLIAM, C. E., M. E., . . . 1877.
529 W. Twentieth St., and 175 W. Eighty-seventh St., New York City.

1877–78, Honorary Assistant in Metallurgy, School of Mines. 1878–81, U. S. Geographical Surveys, West of 100th Meridian. 1881–82, Preliminary Surveys, New Croton Aqueduct and Dam, New York. 1882, Reporting on Mines in Colorado. 1883 to date, Firm of James R. Floyd & Sons, Iron Works. Specialty, Gas Engineering and Gas Works Construction.

FOERSTER, DAVID, E. M., ... 1895.
Box, 4, Woodland Park, Colo., also 5 East Pearl Street, Cincinnati, O.

Chemist, N. J. Zinc and Iron Co. Assayer and Surveyor, West Creek, Colo.

FOLGER, EDWARD P., ... 1894.
80 Quincy Street, Brooklyn, N. Y.

FOSTER, REGINALD GUY, C. E., ... 1883.
16 E. Thirty-first Street, New York City.

FOWLER, ALBERT CASIMIR, C. E., ... 1889,
Cienfuegos, Cuba.

FOWLER, SAMUEL STEWART, A. B., E. M., . . . 1884.
Engineer, The London and British Columbia Goldfields, Box 106, Nelson, B. Col.

1885, Civil Engineering Work, New York. 1886, Assistant Superintendent, Iron Hill Mining and Milling Co., Black Hills, South Dakota. 1887, Assistant Superintendent Galena Reduction Co., Black Hills, South Dakota. 1888, Superintendent, International Smelting Works, Texas. Engineer and Assayer, Bunker Hill and Sullivan Mg. and Conc. Co., Idaho. 1889, Reporting sundry properties. 1890 to date, Superintendent Golden Mining and Smelting Co., Golden, B. C., Canada. Deputy Commissioner World's Columbian Exposition, 1893. Engineer the London and British Columbia Goldfields, Nelson, B. Col., 1896–97.

FOYE, ANDREW ERNEST, C. E., ... 1890.
Member of Firm, Foster & Foye, 52 Broadway, and 163 West Seventy-ninth Street, New York City.

1890–92, Engineer's office, M. W. P. R. R. 1892–94, Tutor in Civil Engineering, School of Mines. 1894–96, Instructor in the same. Contractors Consulting Engineer Nyack Sewerage System, Chief Engineer Inter-State Contracting and Construction Co.

FRANK, JEROME WILLIAM, PH. B., ... 1888.
29 Broadway, New York City.

FREEMAN, WILLIAM HORATIO, C. E., ... 1889.
27 Thames Street, and 157 W. 119th Street, New York City.

Post-graduate in Elect. Engineering, 1889–91. John Tyndall Fellow, 1891–92. Tutor in Elect. Engineering, since 1892. Additional degree of E. E., in June, 1891. Associate Editor *Electric Power*.

FRIEDMAN, SAMUEL, C. E., ... 1892.
Tuscaloosa, Ala.

FURMAN, HOWARD VAN FLEET, E. M., ... 1881.
Room 118, Boston Building, Denver, Col.

1882–88, Assayer and Chemist and Foreman, Germania Lead Works, Utah. Chemist, Globe Smelting and Refining Co., Denver. Assistant Superintendent, Billings Smelter, Socorro, New Mexico. Superintendent, Bailey Smelter, Denver, Colo. 1888 to 1894, Consulting Mining Engineer and Metallurgist, Office in Denver. 1894 and 1895, Chief Assayer U. S Mint, Denver, Colo. 1896, Professor of Mining and Metallurgy, Colorado State School of Mines, Golden, Colo., also office as above.

G.

GARLICHS, HERMAN, E. M., ... 1880.
Care of Cons. K. C. S. & R. Co., Argentine, Kansas.

1880–83, Surveying and Reporting on Mines in Colorado. 1883–87, Assistant

Superintendent, Aurora S. & R. Co., Aurora, Ill. 1887 to 1894, Superintendent Refining Department, Omaha and Grant S. and R. Co. Specialty, Silver and Lead Smelting and Refining. 1894, Metallurgist, Velardena Mining Co. Superintendent Refining Department. Cons. K. C. S. & R. Co. Oct. 1, 1895 to date. Superintendent Smelting and Refining Departments, 1897.

GILDERSLEEVE, ALGER C., C. E., ... 1895.

28 W. 48th St., and 39 Cortlandt Street, New York City.

1889 to 1892, Studied Law; 1892, Laborer; 1893, Transitman; 1894, Assistant Engineer, Department of Docks, New York City, resigned in June, 1894, to accept position as Engineer for John C. Rodgers, Contractor, on construction of the Second Section Harlem River Driveway. Resigned in November, 1895, and opened private office at 39 Cortlandt St., as Engineer and Contractor for Piers, Docks, Foundations and Heavy Masonry.

GIFFORD, STANLEY DEVOL, E. M., ... 1889.

No. 115 Broadway, New York City, N. Y.

Vice-President, Montano Ore Purchasing Co.—Eagle Pass, Mexico.

GILLETTE, HALBERT POWERS, ... 1892.

Asst. State Engineer, Powers Block, Rochester, N. Y.

1892–94, Deputy County Surveyor on highways and bridges; 1894–95, Boat Railway Survey, Dalles, Ore., contractor and designer for highway bridges; 1895, Asst. Summer School of Surveying. School of Mines. Asst. Dept. Physics, 1895. Asst. to State Engineer, N. Y., on Canal Improvements. Assistant New York State Engineer since March 1, 1896.

GODLEY, RICHARD D., JR., E. E., ... 1896.

Whitestone Landing, L. I., N. Y.

GOING, CHARLES BUXTON, PH. B., ... 1882.

President Cincinnati Desiccating Co., Cincinnati and Glendale, O.

Trustee and Secretary and Treasurer, Glendale Water Works, 1892–95.

GOLDSCHMIDT, SAMUEL ANTHONY, A. B., A. M., E. M., PH. D. (Life Member,) . . . . . 1871.

President Columbia Chemical Works, 43 Sedgwick St., Brooklyn, N. Y., and New York City.

Assistant Ohio Geological Survey, 1871. Chemist and Assistant Inspector of Fertilizers, Savannah, Ga., during winters of 1871–75. During summers, Assistant to Dr. Chandler, Inspector New York Board of Health, 1873–75. Reporting on Guano Islands, South Pacific, 1876. General Consulting Practice, 1876–80. Inspector Offensive Trades, New York Board of Health, 1879–88. Treasurer Columbia Chemical Works, 1880 to 1891. Specialty, Ammonia Manufacture.

GOOD, GEORGE MCCLELLAN HOUTZ, E. M., . . . 1886.

Mining Engineer, Osceola Mills, Clearfield, Co., Pa.

1887–91, Engineer to the Houtz Estate, Houtzdale, Pa. 1892, Mining Engineer to the United Collieries Company. 1892, Assistant General Manager of the same. Also in 1895, Assistant Engineer Altoona & Phillipsburg connecting R. R. July, 1895, Chief Engineer of same.

GOODWIN, EDWARD, E. M., ... 1891.
Moscow, Idaho.

July, 1887–October, 1889, on Harlem River Canal, New York. 1891, Assistant in Mineralogy, and to spring of 1893, Assayer for Tombstone Mill and Mining Co., Tombstone, A. T. Spring of 1893, Experimental Cyanide plant at Tombstone, A. T. Fall of 1893–summer 1894, Assayer at Texas Con. Gold Mine, and Assayer and Assistant Superintendent at Bully Choop Mines, Shasta Co., California. December 1894–June 1895, Assayer, Puget Sound Red Co., Everett, Wash. June 1895–October 1895, Assayer and Foreman, Monto Cristo Mining Co., Monto Cristo, Wash. October 1895, Prof. Mining University of Idaho, Moscow, Idaho.

GORDON, JOHN, JR., E. M., ... 1871.
G. O. Gordon, 66–70 Beaver Street, New York City.
Merchant, Edward Johnson & Co., 62 Sas Pedro, Rio de Janeiro, Brazil.

GOSLING, EDGAR BONAPARTE, E. M., PH. D., . . . 1884.
Windsor Hotel, New York City.

Tutor in Mathematics, Columbia University from 1884 to 1885. Draughtsman and afterwards Assistant Engineer in Departments of Docks, New York City, 1886–88. In Manufacturing Business in Paris, France, 1888–89. Tutoring in Mathematics and Engineering Branches in New York, and Superintending building of houses, introducing Culm-burning Furnaces in U. S., 1889–91. In charge of erection of buildings in artificial stone (Beton Coignet), for the Suez Canal Company, Egypt.

GRAFF, CHARLES EVERETT, E. M., ... 1885.
50 Highland Ave., Jersey City, N. J.

1885–87, Assistant Engineer, Central Entre Riano Railroad, Argentine Republic, S. A. 1887–88, Engineer, Arizona Union Mining Co., Prescott, Arizona. 1888–90, Manufacturing Work, Binding Twine and Reapers. 1890–91, Engineer, Eagle Oil Co.

GRANGER, A. D., C. E., ... 1892.
Burhorn & Granger, 136 Liberty St., New York City, and 22 Stuyvesant Ave., Brooklyn, N. Y.

Summer and Fall 1892, with C. W. Hunt & Co., and E. P. Gleason Mfg. Co., as draughtsman. November, 1892–November, 1893, draughtsman. The Link Belt Engineering Co., New York branch. Member of firm of Burhorn & Granger from November 1893 to date. Specialties : Boilers, Engines, Complete Steam and Electric Plants.

GRATACAP, LOUIS POPE, PH. B., ... 1876.
Curator American Museum Natural History, Seventy-seventh St., and Eighth Ave., New York City and West New Brighton (Richmond County), Staten Island, N. Y.

GREENLEAF, JAMES LEAL, C. E., ... 1880.
Consulting Engineer, No. 1, Broadway, New York City, and Llewellyn Park, West Orange, New Jersey.

Special Agent for Tenth Census for Water-power from 1880 to 1882. Since instructing in Engineering, civil and sanitary, in School of Mines, Columbia University. 1891, Adjunct Professor Civil Engineering, Columbia University. Resigned professorship in 1895 and gave exclusive attention to business as Consulting Engineer.

GREENE, DAVID JOY, C. E., M. E. (Sibley College), . 1894.
Standard Silica, Cement Co., Flushing Street, Long Island City, and 300 Oakland Avenue, Brooklyn, N. Y.

June, 1895, graduated from Sibley College, Cornell Univ., with degree of Mechanical Engineer. August 1895, to present time, Supt. of the Standard Silica Cement Co., L. I. City, N. Y.

GRISWOLD, WILLIAM TUDOR, C. E., ... 1881.
U. S. Geological Survey, Washington, D. C., and Boise City, Idaho.

GROSS, LOUIS NATHAN, B. S., E. M., ... 1884.
Merchant and 38 East Fifty-eighth Street, New York City.

GUDEMAN, EDWARD, PH. B., PH. D. . . . . 1887.
Davenport Syrup Ref. Co., Davenport, Iowa.

Student at the Universities of Berlin and Göttingen, 1887-89. Private Assistant with Dr. C. F. Chandler, and Honorary Assistant at the School of Mines. 1889 and 1890, Professor of Chemistry in charge of the Department of Chemistry, Dyeing and Pottery at the Pennsylvania Museum and School of Industrial Art, Philadelphia, Pa. 1890–92, Chemist with the American Glucose Company at Buffalo, N. Y., and Peoria, Ill. 1892–93, Chemist in charge of Peoria Grape Sugar Company, at Peoria, Ill. 1893–97 Chemical Superintendent of the same. 1897, Superintendent Davenport Syrup Refining Company.

GUDEWILL, CHARLES EDWARD, C. E., ... 1890.
P. O. Box 603, Montreal, Canada.

1890–91, Assistant in Engineering Department, School of Mines, under Prof. Trowbridge. 1891 to date, Assistant Engineer Dominion Construction Co., Montreal, Canada.

GUITERMAN, EDWARD WOLF, PH. B., ... 1889.
Passaic Print Works, Passaic, N. J.

1890–96, Chemist Passaic Print Works, Passaic, N. J.

H.

HAAS, EDWARD F., C. E., ... 1894.
Berkeley, Cal.

HAASIS, DUNBAR FERDINAND, E. M., ... 1883.
U. S. S. "Godney," Box 173, and 83 Rector St., Perth Amboy, N. J.

1883-84, Inspector of bridge work, Stony Point, New York. 1885–88, Assayer and Chemist, afterwards General Manager Parral Mining and Milling Co.,

(silver), Mexico, 1889, with Corps of Engineers, U. S. A., on New York Harbor improvements. 1890 to date, Engineer Marion Phosphate Co., Florida, and Engineer Hamburgh Phosphate Co., Florida, Surveying, prospecting and reporting on Phosphate deposits. 1892-93, with U. S. Engineers in charge construction Concrete Fortifications. In charge of Harbor Improvements. Assistant Engineer Dominion Construction Company for pipe laying and Reservoir engineering.

HAFFEN, LOUIS FRANCIS, A. M., C. E., ... 1879.
Commissioner Street Improvements, One-Hundred and Forty-first St., and Third Ave., and 647 Cortland Ave., 23d Ward, New York City.

HALE, ALBERT WARD, A. B., A. M., E. M., . . . 1867.
Department of Public Works, East Twenty-fourth Street, and 81 Clinton Place, New York City.

HALL, ROBERT WILLIAM, E. M., ... 1876.
Chemical Building, University of New York, University Heights, 24 Ward, New York City.

From 1879 to 1888, Chemist to the American Gas Fuel and Light Company and to some associated companies. Since the autumn of 1888, Acting Assistant Professor of General Chemistry in the University of the City of New York. Since the autumn of 1890, also Acting Professor of Analytical Chemistry in the same institution. 1891, Professor of Analytical Chemistry, same institution.

HALLOCK, ALBERT PETER, PH. B., PH. D., . . . 1880.
440 First Avenue, New York City, and 161 Sidney Ave., Mt. Vernon, N. Y.

June, 1880, to October, 1880, with Dr. P. de P. Ricketts. October, 1880, to November, 1887, Chemist Consolidated Gas Co. November 1887, to January, 1889, in the shell lime business. January, 1889, to date, Chemist to Carl H. Shultz, Mineral Water Factory. Specialty, Gas and Mineral Water Chemistry.

HAMILTON, FRANK C., E. M., A. M., ... 1894.
Assayer Brodie Gold Reduction Co., Cripple Creek, Colorado.

1894, Assistant Assayer Colorado Smelting Co., Pueblo Colorado. 1895 to date, Assayer Brodie Gold Red Co., Cripple Creek, Colorado.

HANKINSON, ALBERT WORTHINGTON, C. E., . . . 1893.
114 West Forty-fifth Street, New York City.

HANNA, GEORGE BYRON, A. B., E. M., ... 1868.
Charlotte, N. C.

Chemist and Assistant Geologist, North Carolina Geological Survey. Melter and Assistant Assayer U. S. Assay Office, Charlotte, N. C. Also Consulting Mining Engineer and Chemist, etc.

HANSON, RICHARD COCHRAN, C. E., ... 1894.
74 W. 91st Street., New York City.

HARDING, GEORGE EDWARD (Associate), . . . 1867.
Architect, Postal Telegraph Bldg., New York City, and New Brighton, Staten Island, N. Y.

Fellow American Institute Architect and Member American Society Civil Engineers.

HARRINGTON, THOMAS HENRY, C. E., ... 1889.
Columbia University, and West Chester, West Chester County, N. Y.

July, 1889, to March, 1893, Inspector Clerk and General Superintendent on U. S. Works, Flood Rock, Hell Gate, East River, N. Y. April to November, 1893, in charge of Exhibit of River and Harbor Improvements from New York City and Hudson River, at World's Columbian Exposition, Chicago. 1894 to date, Asst. in Dept. Mechanical Engineering School of Mines, Columbia University.

HARRIS, EDWIN A., PH. B., ... 1889.
Chemist and Manager, The Mamilith Co., and The Arbor-ol-Chemical Co., Poplar Bluff, Mo.

1889-90, Chemist of the Camden Consolidated Oil Company. 1890 to date, Chemist Camden Consolidated Oil Company and agent for oil, mineral and timber lands in West Virginia and Ohio. Chemist to the Phosphorus Works of J. J. Allen's Sons, 2 Chestnut St., Philadelphia, 1892-93. April, 1893, to date, Secretary and Treasurer Globe Steam Heating Company.

HARTE, CHARLES R., C. E., ... 1893.
14 Gordon Street, Jamaica Plain, Boston, Mass.

HASKELL, HARRY GARNER, E. M., ... 1893.
Secretary Repauno Chemical Co., and Hercules Powder Co., Wilmington, Del.

HATHAWAY, NATHANIEL, PH. B., ... 1879.
Swain Free School and 43 Elm Street, New Bedford, Mass.

1879-80, Booth and Edgar Sugar Refinery. 1880-83, Private Assistant to Dr. E. Waller, New York. 1883-91, Teacher of Chemistry and Physics, Swain Free School, New Bedford, Mass., and general analytical work.

HAWLEY, JOHN FRANCIS, C. E. (Life Member), . . 1891.
Finca "El Tambor," San Filipe, Guatemala, C. America.

HERBERT, OCTAVE BRITTON, C. E., ... 1888.
D. B. Britton Co., 40 West Broadway, and 72 West 69th Street, New York City.

HEINSHEIMER, ALFRED MAURICE, C. E., . . . 1887.
Kuhn, Loeb & Co., 27-29 Pine Street, and 17 West Seventieth Street, New York City.

HENDRICKS, HENRY HARMON, PH. B. (Life Member), . 1880.
Hendricks Bros., 49 Cliff Street, New York City.

HERCKENRATH, WALTER AUGUSTUS, A. M., C. E., . . 1892.
Address unknown.

1892–93, Erie City Iron Works and with City Engineer on payments and sewers; Wilmington, Vt., on Railway and General Engineering; Inspector U. S. Dredging Operations, Gowanus Bay. 1893, Temporarily employed in the Mathematical Department, University of Ottawa.

HEWLETT, JAMES MONROE, PH. BB., ... 1890.
Lord & Hewlett, Architects, 123 E. Twenty-third Street, New York City, and 77 Columbia Heights, Brooklyn, N. Y.

1893, With McKim, Mead and White, New York City. 1894, Formed partnership with A. W. Lord as architects.

HILDRETH, WALTER EDWARDS, C. E., E. M., . . 1877.
52 Broadway, and 165 West 87th Street, New York City.

HILL, WILLIAM, C. E., ... 1882.
Agent Collins Company, Box 196, Collinsville, Conn.

One year practical experience in manufacture of crucible steel. Two years draughtsman and Assistant to Master Mechanic of company manufacturing crucible steel, bar-iron, edge tools, plows and wrenches. Engineer in charge of reconstruction of a dam 600 feet long, 32 feet high, at Otis, Mass. 1886–1891, Assistant Superintendent for the Collins Company, manufacturing principally edge tools. November 1, 1891, appointed Agent of the Collins Company, with general charge of plant at Collinsville, Conn., employing about 650 men, which position he still holds.

HINMAN, BERTRAND CHASE, Ph. B., A. M. (1892), . 1890.
Supt. Nellie Bly Gold Mining and Reduction Co., and Box 46, Boulder, Colo.

Since June, 1890, Chemist to the Iron Clad Manufacturing Company, engaged in the manufacture of sheet-iron enamelled ware.

HOLBROOK, FRANCIS NEWBERRY, C. E., ... 1876.
42 Pine Street, New York City, and Box 395, Tarrytown, N. Y.

From fall, 1876, to spring, 1880, Assistant Assay Laboratory School of Mines. Spring and summer on Geological Survey, West Texas. Then to 1884, spring, Superintendent Corralitos, Co., Chihuahua, Mexico. 1884–87, expert work, office, El Paso, Texas. Summer and Fall, 1887, Superintendent of United Verde Copper Company, Arizona. 1888, spring, on geological work for the Southern Pacific Company in West Texas. Summer and Fall, running gold mine and Mill for self in Arizona. 1889-90, Manager for U. S. Circuit Court in suit between the Con. Kansas City Smelting and Refining Company and the Guadalupe Company, in Nuevo Leon, Mexico. 1890 to February, 1891, employed by the Compañia Métalurgica Mexicana. March and April, 1891, charge of Copper Smelter, Tucson, Arizona. Expert work until 1892, when returned to Comp. Metal, Mexico. Still employed by the Compañia Metalurgica Mexicana and the Mexican Northern Railway Co.

HOLDEN, EDWIN C., E. M., ... 1896.
17 West 132d Street, New York City.

HOLDEN, EDWARD HENRY, C. E., ... 1878.
1074 Boston Avenue, New York City.

HOLLERITH, HERMAN, E. M., Ph. D. (1890), . . . 1879.
Electrician and Expert, 1054 Thirty-first St., Washington, D. C.

HOLLICK, ARTHUR, Ph. B., ... 1879.
Geol. Dept. Columbia College, New York City, and New Brighton, N. Y.

Superintendent Mexican Mine, Mariposa, Cal., 1880. New York City Health Department Inspector from 1881–90. Sanitary Engineer from 1890–91. Special Inspector, 1892. Special Expert and Inspector of Offensive Trades, New York State Board of Health, both in consultation and field work, from 1883 to date. Board of Health, Village of New Brighton; 1886–92, a member of the Board, Board of Health, Long Island City, Sanitary Adviser, 1890. In general practice as a sanitarian from 1883 to date. U. S. Geological Survey—engaged in collecting specimens in the Territories, in 1882. Appointed Fellow in Geology, Columbia College, January, 1890; reappointed, 1891; Assist., 1892. 1893, Tutor in Geology. Recording Sec'y. Torrey Botanical Club, N. Y., 1883–88. Secretary Natural Science Association of Staten Island, 1881 to date. Associate Editor *Bulletin*, Torrey Botanical Club, 1888 to date. Librarian New York Academy of Sciences, 1894 to date.

HOLLIS, HENRY LEONARD, E. M., ... 1885.
525 The Rookery, Chicago, Ills.

1885, Assistant Chemist Edgar Thompson Steel Works. 1885–87, Assistant Chemist, North Chicago Rolling Mill Company. 1887–90, Chief Chemist, North Chicago Rolling Mill Company, which, in 1889, became, by consolidation, part of the Illinois Steel Company. 1890, member of firm of Rattle, Nye & Hollis, Analytical Chemists and Mining Engineers. 1893, Member of firm of H. L. Hollis & Co., Analytical Chemists and Mining Engineers. Vice-President Potter & Hollis Foundry Co., and Vice-President Potter & Hollis Engineering Company.

HOLLIS, WILLIAM, C. E., ... 1887.
Box 180, Eagle Pass, Texas. Agent for Alamo and Coahuila Coal Companies.

HOLT, MARMADUKE BURRELL, E. M., ... 1889.
Silverton, Colo., and 287 Lexington Avenue, New York City.

1889–90, Student in course of Electrical Engineering, School of Mines. 1890–91, with Aspen Mining and Smelting Company, serving as Mining and Electrical Engineer. 1891 to fall of 1892, Agent and Electrical Engineer with the "C. and C." Electric Motor Co., N. Y. City and Denver. 1892–93, Assayer Colorado Smelting Co., Pueblo, Colo.

HOOKER, WILLIAM AUGUSTUS, A. B., A. M., E. M., . 1869.
Hooker & Lawrence, 145 Broadway, New York City.

HOOPER, FRANK CYRUS, MET. ENG., ... 1890.
North River Garnet Co., Ticonderoga, N. Y.

1890–91, Assistant Engineer De Lemar Mining Co., Limited. 1892–93, American Graphite Co., Spring, 1893, Investigation and report on Sisal Hemp Industry in The Bahamas for The Inagua Fibre Co. Summer and Fall, Erection of Concentrating Plant in Adirondacks. Sup't. North River Garnet Co., from 1893 to date.

HOPKE, THEODORE M., PH. B., ... 1880.
Supt. O. H. Dept. Apollo I & S. Co., Apollo, Pa.

August, 1880, November, 1881, Analytical Chemist with Ledoux & Co., New York. November, 1881, to November, 1885, Member of the firm of Elliott, Hopke & Mattison, Analytical and Consulting Chemists and Assayers. July, 1886, to November, 1889, Chemist for London Steel Co., of Pittsburgh, Pa., also had charge of Physical testing department. November, 1889–1894, Manager Open-Hearth department of above Company, having full charge of manufacture of all grades of steel made by the company, also building of open-hearth furnaces. 1894, Secretary and Assistant to General Manager, McKeesport Supply Company. Supt. O. H. Dep't., Apollo Iron and Steel Co., Apollo, Pa.

HORNE, WILLIAM DODGE, PH. B., ... 1886.
Yonkers, N. Y.

June, 1886, to December, 1887, Chemist to Fulton Sugar Refinery, Brooklyn, N. Y. October, 1887, to December, 1887, Assistant Instructor in Chemistry, School of Mines, Columbia University. December, 1887, to June, 1888, Chemist to St. Louis Sugar Refinery, St. Louis, Mo. October, 1889, to October, 1889, Chemist to Standard Sugar Refinery, Boston, Mass. November, 1889, to present time, General Analytical and Consulting Chemist. January, 1890, to January, 1893, Consulting Chemist to Delaware Sugar House, Philadelphia. January to June, 1891, Instructor in Analytical Chemistry in Rutgers College, New Brunswick, N. J. May, 1893, to present time, Consulting Chemist to National Sugar Refining Co., Yonkers, N. Y. Laboratory and office in New Brunswick from November, 1889, to September, 1893. From September, 1893, to present time in Yonkers, New York. In June, 1894, received from Columbia College the degree of Ph.D. in the Department of Chemistry and of Mechanical Engineering.

HOWE, EPENETUS, E. M. (Life Member), . . . 1886.
Box 68, Monterey, Mexico, and North Salem, Westchester County, N. Y.

Assayer and Chemist with the El Paso Smelting Co., and the Argentine Works. Kansas, 1887–1889, and with Lucia Constancia Esmeralda Sierra Mojada Coahuila, Mexico, 1889. Assayer, Chemist and then Superintendent 1889–1895. May, 1895 to date, engaged in irrigation mining and other engineering work for self on contract.

HUMBERT, WILLIAM SCOTT, E. M., ... 1883.
Niagara Falls, N. Y.

1883–85, Surveys and location of Tunnel for New Croton Aqueduct. 1885–87, Construction work New Croton Aqueduct and extensive Topographical Survey of the Croton Valley. 1887–88, in charge of construction as Assistant Engineer at shafts No. 21, No. 22 and No. 23 New Croton Aqueduct (night shift). 1888–91 Assistant Engineer in charge of the construction of two large dams and tunnels

connecting the two basins of Double Reservoir "I," located two miles east of Brewster, N. Y., on the east branch of the Croton River. 1891, Special Assistant Engineer Cataract Construction Company.

HUNT, FREDERICK FURNEAUX, E. M., C. E., . . . 1876.
77 Pine Street, New York City, and New Brighton, S. I.

HUNTINGTON, FREDERICK WOLCOTT, E. M., . . . 1885.
Address unknown.

HUNTOON, L. D., E. M., PH. G., ... 1895.
95 Bridge Street, Patterson, N. J.

August to November, 1895, Assistant Chemist Phila. Smelting and Refining Co., Pueblo, Colo. December 1895 to date, Assayer American Reduction Co., (Cyanide Mill), Florence, Colo. Fall of 1896 with Picketts & Banks, New York City, making Metallurgical tests.

HURLBUT, ELISHA DENISON, JR., C. E., ... 1890.
106 Hicks Street, Brooklyn, N. Y.

1890–91, at Columbia University Law School. 1891–93, Assistant in Mechanical Engineering, School of Mines.

HUTTON, FREDERICK REMSEN, A. B., A. M., E. M., C. E., .
PH. D. (Life Member), ... 1876.
Columbia, and 296 Lexington Avenue, New York City.

1876–77, Assistant in Engineering, School of Mines. 1877–82, Instructor in Mechanical Engineering. 1882–91, Adjunct Professor Mechanical Engineering. 1891, Professor Mechanical Engineering.

HYDE, FREDERICK S., PH. B., ... 1893.
Brooklyn Dept. of Health, and 215 Schermerhorn Street, Brooklyn, N. Y.

1893–94, Investigations in Glass for L. C. Tiffany, New York City. Assistant Chemist, Brooklyn Department of Health, May, 1894, to date.

HYDE, HENRY ST. JOHN, PH. B., ... 1896.
210 East 18th Street, New York City.

I.

IHLSENG, AXEL OLAF, B. S., E. M., C. E. . . . 1877.
Carthage, Mo.

1877–82, Chief Chemist, Havemeyer Sugar Refining Co., Brooklyn, E. D. 1882–90, U. S. Dep. Mining Surveyor, District of Colorado. 1882–83, Chemist and Assayer, La Plata Smelter, Leadville, Colo. 1883, Metallurgist, Martha Rose Smelter, Silverton, Colo. 1884, Assayer, Stoiber Sampling Works, Silverton, Colo. 1885, Duyckinck, Schuyler & Ihlseng, Ore Samplers, Silverton, Colo. 1886–90, Manager of Mt. Queen Mining Co., Reliance Mining Co., Brown Mining Co., and the Hale Mines, Silverton, Colo. 1890–92, Operating Zincite Mine and others near Webb City, Nevada, and in constructing concentrating plants. Manager Pleasant Valley Mines, Carthage, Mo.

ILES, MALVERN WELLS, PH. B., PH. D. (Life Member), . 1875.
Superintendent Globe Smelting Co., Denver, Colo.

1875–76, Assistant to Dr. Waller in the Qualitative Laboratory, School of Mines. 1876–78, Chemical Fellow, Johns Hopkins University. 1878–79, Assayer and Chemist, in Colorado. 1879–80, Assayer at the Smelting Works of J. B. Grant, Leadville, Colo. 1880–83, Chemist of the Grand Smelting Co., Leadville, Colo. 1883–86, Metallurgist, The Omaha & Grant, S. and R. Co., Denver, Colo. 1886–87, Metallurgist, The Holden Smelting Co, afterwards changed to the Globe S. & R. Co. 1887–95, in present position. Dr. Iles has contributed articles upon Assaying, various new Chemical methods, Mineralogy and Metallurgy in various publications.

INGERSOLL, WILLIAM HALSEY, A. B., A. M., LL. B., E. M. (Life Member), ... 1870.
Northport, Suffolk County, N. Y.

1875–78, Assistant in Engineering, Columbia University. 1878–81, Assistant in Mechanics and Astronomy. 1881–87, Manufacturing tinware, Portland, Conn. 1887, to date, retired on account of ill health.

INGRAM, EDWARD LOVERING, C. E., ... 1885.
403 D. S. Morgan Building, and 378 Pearl St., Buffalo, N. Y.

1885–86, U. S. Inspector of River and Harbor Improvements, Delaware. 1887–89, U. S. Surveyor and Inspector, River and Harbor Improvements, New York and New Jersey. 1890–91, U. S. Assistant Engineer, River and Harbor Improvements, Florida. 1891–94, Principal Assistant Engineer, International Boundary Survey, United States and Mexico. 1895 to date, Consulting Engineer.

J.

JACKSON, OSWALD, C. E., ... 1892.
550 Park Ave., New York City.

1892–93, Offices of Engineering M. W., U. R. R's. of N. J. Div., P. R. R. 1893, Engineer on Corps of Principal Assistant Engineer, U. R. R's. of N. J. Div., P. R. R. 1895, Assistant Engineer, the New York Steam Company. 1896, Engineer Inspector Dept. of Public Works, New York City.

JACOBS, DAVID MARK, PH. B., ... 1887.
R. J. Jacobs, 41 New Street, and 30 W. Thirty-eighth Street, New York City.

JACOBS, SOLOMON JOSEPH, PH. B., ... 1887.
R. J. Jacobs, 41 New Street, and 30 W. Thirty-eighth Street, New York City.

JANEWAY, JOHN HOWELL, E. M., ... 1886.
John A. Roebling's Sons Co., and 124 West State Street, Trenton, N. J.

1886, Underground and Surface Surveyor for Cooper, Hewitt & Co. 1887–91, Draughtsman and Designer and Constructing Engineer of Wire Rope Tramways in Montana, Oregon, Alaska and California for the Trenton Iron Company, Trenton, N. J.

JENKS, ARTHUR WILTON, E. M., ... 1886.

Superintendent Establecimiento Mineral, Casapalca, Peru, S. Am.

Summer 1886, New Jersey on Geological Work. 1886–87, in Cerro de Pasco, Peru, S. A. Assayer and Chemist to the commission examining that silver mining district. Spring, 1887, in New York, Chemist with Ledoux & Co. 1887–88, In Aurora, Ill., Assistant at the works of the Chicago and Aurora Smelting and Refining Company. Summer and Fall, 1888, In Dutch Guiana, S. A., Assayer and Assistant in the examination of gold deposits. Fall 1888 to 1893, in Aurora, Ill,, Assistant Superintendent at the Aurora Works of the Chicago and Aurora Smelting and Refining Co. 1883, Superintendent Kootenay Reduction Co. 1894, Superintendent Balbach Smelting and Refining Co., Newark, N. J.

JEUP, BERNARD JOHN THEODORE, C. E., . . . 1887.

Assistant City Engineer, 119 Walcott Street, Indianapolis, Ind.

JOBBINS, F. H., PH., B., ... 1895.

Jobbins & Van Ruymleke, Analytical Experts and Mfg. Chemists, Aurora, Ill.

JOHNSON, ARTHUR GALE, E. M., ... 1885.

Jensen, Utah.

JOHNSON, ELIAS MATTISON, PH. B., ... 1878.

Isaac G. Johnson & Co., Spuyten Duyvil, N. Y.

JOHNSON, GILBERT HENRY, PH. B., ... 1878.

Isaac G. Johnson & Co., Spuyten Duyvil, N. Y.

JOHNSON, ISAAC BRADLEY, E. M., ... 1879.

Isaac G. Johnson & Co., Spuyten Duyvil, N. Y.

JOHNSTONE, WM. B., C. E., ... 1895.

47 Central Avenue, New Brighton, S. I., New York.

JONES, JOHN ELMER, E. M., ... 1893.

Asst. Supt. Mill Creek Coal Co., New Boston, Pa., and Hazleton, Pa.

JONES, WILLIAM DENISON, PH. B., ... 1888.

Hecker, Jones, Jewell Milling Co., 206 Produce Exchange, New York City, and 62 Clark Street, Brooklyn, N. Y.

JOPLING, REGINALD FURNESS, E. M., ... 1889.

Jopling & Escobar, Engrs., Room 508 Cuyahoga Bldg., Cleveland, O.

November, 1889, to February 1890, Chemist, Otis Steel Co., Ltd. February, 1890–92, Assistant Manager American Wire Co. Vice-President of same, January, 1893.

JOUET, CAVALIER HARGRAVE, PH. B., PH. D., . . 1882.

Guggenheim Smelting Co., Maurer, N. J., and Roselie, N. J.

Analytical Chemist with Ledoux & Rickette, 1882–85. Analytical Chemist with G. H. Nichols & Co., Acid Manufacturers at Laurel Hill, L. I., from 1885–88. Work comprising analyses of their various products and a partial supervi-

sion of their manufacture. Analytical Chemist from 1888 to present time with Ricketts & Banks. Analyst with Guggenheim Smelting Co., from March, 1896, to present time.

K.

KASTNER, J. C., PH. B., ... 1894.
744 Broadway N. Y. City, and Oyster Bay, L. I., N. Y.

KELLY, WILLIAM, A. B., E. M., ... 1877.
Vulcan, Dickinson Co., Mich.

1876, '79, '80, Assistant Superintendent, Chemical Copper Co., Phœnixville, Pa. 1878, Chemist, Nimrod Furnace Co., Youngstown, Ohio. 1881–84, Superintendent, Kemble Coal and Iron Co., Riddlesburg, Pa.; 1885, Superintendent, Glamorgan Iron Co., Lewistown, Pa.; 1886–89, Superintendent, Kemble Iron Co., Riddlesburg, Pa.: In charge of Blast-furnaces, Coal Mines, Coke Ovens, Ore Mines, Quarries, Railroads, etc. 1880 to date, General Superintendent and General Manager Penn Iron Mining Co., Vulcan, Mich.; in charge of Iron Ore Mines on the Menominee Range, Lake Superior. Also, 1885–89, President Board of Examiners of Bituminous Mine Inspectors of Pennsylvania.

KEMP, JAMES FURMAN, A. B., E. M., ... 1884.
Prof. Geology, Columbia University, School of Mines, and 211 W. 139th St., New York City.

Several months with the Rand Drill Co., 1883–1884. Private Assistant to Prof. J. S. Newberry, 1884–85. Student of Geology and Mineralogy at the Universities of Leipzig and Munich, Germany, 1885–86. Instructor in Geology at Cornell, 1886–88. Assistant Professor of Geology and Mineralogy, 1888–91, and Secretary of the Faculty, 1888–89. Have traveled much in the West, and for five summers past have been working on the Geology of the Adirondacks, chiefly as Assistant to the State Geologist, Prof. Jas. Hall. Am especially engaged on Inorganic and Economic Geology. 1891, Adjunct Professor of Geology, School of Mines, Columbia University. Professor, 1892. Secretary N. Y. Acad. of Science since 1893. Editor School of Mines Quarterly, 1895–97. Manager Am. Inst. Mining Engrs, 1896–99. At work on Geology of Eastern Adirondacks for U. S. Geol. Survey, Aug. to Sept., 1896.

KINSEY, FRANK WILMARTH, C. E., ... 1891.
50 Broadway, New York City, and 10 South Street, Newark, N. J.

Assistant to Engineers' Rapid Transit Commission, 1891–92. Engineer of Construction East Providence Water Works, 1892. Designing Engineer with S. M. Gray, 1892–93. 1893, Manager for R. W. Hildredth & Co.

KIRBY, G. T., E. E., ... 1895.
School of Law, Columbia University, and 158 W. 45th Street, New York City.

KISSAM, HENRY SNYDER, PH. B., ... 1886.
Architect Psi, Upsilon Club, 64 West 39th St., New York City.

1888–89, Manager of Office of Pickles & Sutton, Architects, Tacoma, Washington. 1889-90, Practicing Architecture with P. W. Morris, under firm name of

Kissam & Morris, Tacoma, Washington. 1890–92, Practicing Architecture alone under name of Henry Snyder Kissam, Tacoma, Washington. 1892, Practising Architecture with Jno. G. Proctor, under firm name of Proctor & Kissam, Tacoma, Washington. During 1893–94, in New York City, as student of Construction, with J. C. Cady & Co. 1895–96, Superintendent of Construction, Parish & Schneider, Architects, New York City.

KLEPETKO, FRANK, E. M., ... 1880.
Manager of Smelting Plants of Boston and Montana, Consolidated Copper and Silver Mining Co. at Great Falls.

Superintendent Smelting Department, Tamarack, Osceola Copper Manufacturing Company, Collar Bay, Mich. At present Superintendent of Construction of the Great Falls Smelter, for the Boston and Montana Consolidated Copper and Silver Mining Company. Address, Great Falls, Montana.

KOCH, EDWARD CABOT, E. M., ... 1879.
120 E. 91st Street, New York City.

1880–82, Assayer and Chemist at Smelters, Leadville, Colo. 1883–88, Surveyor and Assistant Superintendent, L. A. G. Mfg. Co., Colo. 1889-92, Assistant General Manager E. G. Co., Ltd., and V. G. Co., Ltd., Rocky Bar, Idaho. 1892 to 1896, examining mining properties. 1895–96, Manager Elmore Mine, Rocky Bar, Idaho.

KOEN, JOSEPH JOHN, C. E., ... 1888.
Board of Health, 301 Mott Street, New York City, and Pearsalls, N. Y.

1889–90, Computer on New Croton Aqueduct. 1890-91, to date, Sanitary Engineer on New York City Board of Health.

KUNHARDT, WHEATON BRADISH, E. M. (Life Member), . 1880.
Carpenter Steel Co., 1 Broadway, New York City, and New Brighton, N. Y.

1880–82, Travel and Study in the West and in Europe. 1883–88, Engineer for the Bower-Barff Rustless Iron Co., and Assistant of Geo. W. Maynard in consulting work on Iron-mines and Ore-dressing. 1888–89, First Assistant Engineer of the Boston Heating Co. 1890-91, Diamond Drill Exploration of Coal Deposits in Rhode Island. Report on Direct Steel Processes and on Magnetic Separations for Iron-ores. Acting Secretary of the American Institute of Mining Engineers for four months. 1893, President of the Osceola Placer Mining Company. 1894, with Carpenter Steel Co., 1 Broadway, New York City. 1895, Vice-President Carpenter Steel Co.

KURTZ, EDWARD LAURENCE, E. M., ... 1893.
17 Pittsburgh Street, New Castle, Pa.

L.

LACOMBE, CHARLES FREDERICH, E. M., ... 1885.
The Mountain Electric Co., P. O. Box 1545, and 535–536 Seventeenth Street, and 1811 Grant Avenue, Denver, Colo. Also, University Club, New York City.

1885–86, Assayer and Surveyor and Foreman of Lucky Boy and South Galena Mines, in Bingham, Utah. 1886–88, Assistant Instructor in Assaying, and Fellow in Chemistry, School of Mines, Columbia University, N. Y. 1888–90, Examining Gold and Silver Mines in Colorado, Utah, Montana, Arizona and Old Mexico, 1890, Testing Electrical Apparatus in Virginia City, Nevada. 1890, Manager of the Gilpin Co. Light, Heat and Power Co., Central City, Colo. 1890 to date, President and Manager The Mountain Electric Co. Specialty, Installing Electric Light and Power Stations, and adapting electric light and power for mining purposes.

LAHEY, JOSEPH, E. M., ... 1887.
162 E. 86th St., New York City.

LAHEY, RICHARD, E. M., ... 1887.
Millard & Lahey, 1429 Chestnut Street, Phila., Pa.

LAMB, ANDREW JOHNSON, E. M., ... 1884.
L. & N. R. R. Co., Gallatin, Tenn.

June, 1884, to June, 1887, New York Croton Aqueduct, Draughtsman. June, 1888, to Sept., 1890, Assistant Engineer, L. & N. Railroad. Sept. 1890, to June, 1891, Assistant Roadmaster, Knox Div., L. & N. Railroad. June, 1871, to date, Assistant Engineer L. & N. R. R. 1896, Roadmaster L. & N. R. R., Gallatin, Tenn.

LANGMUIR, ARTHUR C., ... 1893.
Care Messrs. Ricketts & Banks, Waverly, N. J.

LANGTHORN, JACOB S. (Associate), ... 1891.
Asst. in Charge of Docks and Bridges, Dept. City Works, and 94 Clinton Street, Brooklyn, N. Y.

LAWRENCE, BENJAMIN BOWDEN, E. M., ... 1878.
Hooker & Lawrence, 810 Boston Avenue, Denver, Colo.

1878–84, Superintendent, Montezuma S. M. Co., and of other mines of Summit Co., Colo. 1884–91, Lessee and Operator of Mayflower and Pelican-Dives Mines, Clear Creek Co., Colo. In 1886, Formed partnership with W. A. Hooker, E. M., Class of 1869, with office at 145 Broadway, as Consulting Mining Engineers. I make a specialty of operating under lease or otherwise, true fissure Gold and Silver Mines, also Concentration of Gold-silver ores. 1893–94, Georgetown, Colo., at the Pelican-Dives Mines. 1895, Manager the Perigo Gold Mines, Colo.

LEARY, DANIEL JAMES, C. E., E. M., ... 1881.
43 East Twenty-fifth Street, New York City.

1882 to date, Constructing Highway and Railroad Bridges, Wharves, Docks, Dredging and Harbor Improvements generally, in vicinity of New York City, as Designing and Supervising Engineer, as well as Contractor in most instances. In general, make a specialty of both Engineering and Constructing work, or Engineering work alone, in this branch of the profession.

LEARY, GEORGE, C. E., ... 1891.
43 East Twenty-fifth Street, New York City.

LEAVENS, HARRY WENMAN, E. M., ... 1875.
Broken Hill Refinery, Port Pirie, South Australia.

LEBOUTILLIER, CLEMENT, PH. B., ... 1881.
High Bridge, N. J.

1884–7, Assistant Chemist, Cambria Iron Co. 1887-92, Chemist, Eliza Furnace. March, '92, to date, Chemist, Taylor Iron and Steel Company.

LEDERLE, ERNST JOSEPH, PH. B., ... 1886.
Chief Chemist, New York City Health Dept., Criminal Court Bldg., Centre and Franklin Sts., and 471 W. 143d St., New York City.

1886-87, Hon. Fellow Quant. Anal. and Assist. Intr. Gen. Chemistry, School of Mines. 1887–88, Chemist, Cranmoor Farm, Tom's River, N. J. 1888–89, Asst. Chemist, New York City Health Dept. 1890-91, Chemist and Supt., Reed & Carnrick, New York. 1891 to March, 1896, Asst. Chemist, New York City Health Dept. March, 1896, to date, Chief Chemist, also Consulting Chemist to Health Officer, Port of New York.

LEDOUX, ALBERT REID, M. S., PH. D. (Associate), . . 1874.
Ledoux & Co., 9 Cliff St., and 39 W. 50th St., New York City.

LEE, GEORGE BARSTOW, E. M., ... 1885.
Supt. Arkansas Valley Smelting Co., Leadville, Colo.

1885, Assayer, Butte, Montana. 1886–87, Assayer, Kansas City Smelting and Refining Co., Argentine, Kan. 1887-90, Assistant Superintendent, Rio Grande Smelting Co., Socorro, New Mexico. 1890–93, Superintendent, Rio Grande Smelting Co., Socorro, New Mexico. 1894, Superintendent, Guggenheim Smelting Co. 1896, Supt. San Felipe Smelting Co., Mexico. 1897, Supt. Arkansas Valley Smelting Co., Leadville, Colo.

LEGGETT, THOMAS HAIGHT, E. M., ... 1879.
P. O. Box 485, Johannesburg, S. A. Rep.

1880, Assistant Engineer, New York River and Harbor Surveys. 1881–83, Superintendent of Mining Properties in the Batopilas District, Chihuahua, Mexico. 1884, Travelling in the West, through the principal Mining Camps, Butte, Leadville, etc. 1884-87, Mining Engineer to the New York and Honduras Rosario Mining Co., at San Juancito, Honduras. 1888, Manager of Mudsill Mining Co., Fairplay, Colo.; office, 23 Bucklersbury, London, E. C. 1889–90, General Manager, Darien Gold Mining Co., Ltd., of Cana, Rep. of Colombia. 1891–93, President and Manager, Standard Consolidated Mining Co. Cons. Engr. S. Neumann & Co., of London and Johannesburg since July, 1895.

LENOX, LIONEL REMOND, PH. B. . . . . 1888.
Professor of Analytical Chemistry, Leland Stanford, Jr., University, Palo Alto, California.

LEVY, ALBERT LINCOLN, E. M., ... 1890.
810 Lexington Avenue, New York City.

LIBAIRE, EDWARD WILLIAM, C. E., ... 1894.
150 W. Forty-ninth Street, New York City.

LIEBMANN, ALFRED, C. E., ... 1893.
50 Broadway and 38 E. Seventy-second Street, New York City, member of firm of R. W. Hildreth & Co.

LILLIENDAHL, ALFRED WHIPPLE, E. M. (Life Member), . 1883.
Superintendent, Mazapil Copper Co. (Ltd.), Concepcion del Oro, Estado de Zacatecas, Mexico, and Lakewood, N. J.
1883–85, Assistant Supt. Aurora Smelting and Refining Co., Aurora, Ill. 1885–87, Assistant Supt. Grande Milling and Refining Co., Guanajuato, Mexico. 1888–97, Superintendent of the Mazapil Copper Co., Ltd., Concepcion del Oro, Zacatecas, Mexico. Superintendent, Coahuila and Zacatecas Railroad.

LILLIENDAHL, FRANK ARMSTRONG, E. M., . . . 1891.
Assistant Superintendent and Metallurgist, Mazapil Copper Co. (Ltd.), Concepcion del Oro, Estado de Zacatecas, Mexico (via Laredo, via Saltillo).
1891–97, as above.

LILLIE, SAMUEL MORRIS, E. M., ... 1874.
328 Chestnut Street, Philadelphia, Pa.
1874–75, Chemist, Kings County Refining Co., Green Point, L. I. 1876–85, Chemist, Franklin Sugar Refinery, Philadelphia, Pa. 1886–87, Sugar Engineer and Chemist, 1888–90, Vice-President and Manager of "The Sugar Apparatus Manufacturing Co.," a Company organized under the laws of Pennsylvania, to operated under his patents. 1891, President of said Company.

LIPPS, HENRY, JR., C. E., ... 1888.
897–901 E. 149th St., and Elliott Ave. near Elizabeth St., New York City.
From July, 1888, to August, 1889, Assistant Engineer Maint. of Way, Dep. R. & D. R. R., W. N. C. & Va. Mid. Div. August, 1889, to January, 1890, Supervisor Track, N. C. Div. R. & R. R. January, 1890, Engineer Maint. of Way, N. C. Div. R. & D. R. R.

LITTLE, WILLARD PARKER, E. M., PH. B., . . . 1881.
Little & O'Conner, Architects, Astor Court Bldg., 20 West Thirty-fourth Street, New York City.

LIVINGSTON, ARCHIBALD ROGERS, C. E., . . . 1891.
20 North Washington Square, New York City.
Since November, 1891, in employ of Lackawanna I. & S. Co., Scranton, Pa.

LONGACRE, LINDSAY B., M. E., B. D. (Drew Theol. Seminary 1896), ... 1892.
Tarrytown and Spuyten Duyvil, N. Y.
Graduated with class of 1896, Drew Theological Seminary.

LORD, FREDERICK REUBEN, C. E., ... 1892.
General Manager, Clifton Coal Co., Bay Street, cor. Vanderbilt Ave., Clifton, and Box 228, Stapleton P. O., Richmond Co., N. Y.

LOVE, EDWARD GURLEY, A. M., PH. B., PH. D., . . 1876.

Analytical and Consulting Chemist, Gas Examiner, Department Public Works, 122 Bowery, and 80 East 55th Street, New York City.

LOWENSTEIN, JOSEPH, PH. B., ... 1896.
205 Belmont Avenue, Newark, N. J.

LUDLAM, FRANK (Associate), ... 1895.
Heins & La Farge, 7 Beekmau St., and 18 W. 16th St., New York City.

LUDLOW, EDWIN, E. M., ... 1879.
Superintendent Choctaw Coal and Railway Company, Hartshorn, Indian Territory.

1879–81, Assistant Engineer in charge of hydrographic work on Delaware River under U. S. Engineer. 1881, Assistant Engineer Mexican National Railroad, Mexico. 1882–89, Assistant Superintendent, then Superintendent, for Pennsylvania Railroad coal mines at Shamokin, Pa. 1889, to date, Superintendent of Mines, Choctaw Coal and Railroad Company, Hartshorn, Indian Territory.

LUQUER, LEA MCILVAINE, C. E., PH. D. (1894), . . 1897.
Tutor in Mineralogy, School. of Mines, New York City, and 8 Pierrepont St., Brooklyn N. Y.

Summer of 1897, Assistant in Geodetic Surveying with Professor Rees. Summer of 1897, Assistant in Surveying with Professor Monroe. Summer of 1888, Assistant in Geodetic Surveying with Prosessor Rees. 1887–90, Fellow in Mineralogy, School of Mines. 1890, Assistant in Mineralogy, School of Mines. 1891 to date, Tutor in Mineralogy, School of Mines. 1895–96, Lecturer and Instructor in Mineralogy during absence of Professor Moses in Europe.

LUQUER, THATCHER TAYLOR PAYNE, C. E., E. E., (1892), 1889.
Care of Metropolitan Telephone and Telegraph Co., 18 Cortlandt Street, New York City, and Bedford, N. Y.

1890, Fellow in Engineering. 1890–91, Fellow in surveying and Practical Mining. 1891, Assistant in Mining, Columbia University, School of Mines. 1892, with H. Ward Leonard & Co., New York City. 1893, Engineer, Union Electric Co., New York City. 1894, Engineer the Fiber Conduit Company, New York City. 1895, Engineering Dept. M. T. & T. Co.

LUSK, GRAHAM, A. M., PH. B., PH. D., ... 1887.
Assistant Professor of Physiology at the Yale Medical School, New Haven, Conn. Address: 47 East Thirty-fourth St., N. Y. City.

1887–1888, Student at Munich. 1889, Student at Munich; also at Bellevue Hospital Medical College, N. Y. 1890, Studied at Bellevue; afterwards in Munich. 1891, studied in Munich and was later appointed Instructor of Physiology at the Yale Medical School. 1892, Assistant Professor of Physiology. 1895, Professor of Physiology. 1896, contributed the chapter "The Chemistry of the Animal Body" to the American Text-book of Physiology.

LUTTGEN, EBERHARD, PH. B., ... 1884.
Wissahickon Chemical Works, Ambler and Chelten Hills, Wyncote P. O. Pa.

1884-85, Assistant Chemist, Crane Iron Company, Catasauqua, Pa., 1885 to date, Chemist and Manager, Keasbey & Mattison's Chemical Works, Ambler, Pa. Specialty, manufacture of magnesia.

LYMAN, FRANK, A. B., M. E., ... 1878.
Deputy Commissioner City Works, Room 15 Municipal Building, and 50 Remsen Street, Brooklyn, N. Y.

M.

MCCAFFERY, RICHARD S., E. M., ... 1896.
Care The Backus & Johnston Co., Lima, Peru, S. A., and *for mail* 316 East 124th Street, New York City.

MCCONWAY, WM. LYTLE, E. M., ... 1896.
Bedford Avenue, Pittsburgh, Pa.

MCILHINEY, PARKER C., A. M., PH. D., . . . 1892.
School of Mines, Columbia University, New York City, and 72 Monticello Ave., Jersey City, N. J.

Summer of 1892, Chemist Fibre Pipe Co. 1893-94, Hon. Asst. in Assaying. 1894, Asst. in Metallurgy.

MCKENNA, CHARLES FRANCIS, PH. B., ... 1883.
221 Pearl St., and 144 W. Ninety-ninth St., New York City.

1883-84, Chemist Havemeyer Sugar Refining Company, Jersey City, N. J. 1885-86, Chemist Cambria Company, Johnstown, Pa. 1887-90, Chemist Edgewater Lime Works, Edgewater, N. J. 1890, Chemist Jas. J. McKenna & Bros., Brass Founders, 424, 426 East Twenty-third Street, New York City. 1893, Director, Physical Testing Department, Laboratories, Dr. G. E. Moore, 221 Pearl Street, New York City.

MCKIM, ROBERT ALBERT, C. E., ... 1884.
Room 213, 280 Broadway, New York City, and Rochelle Park, New Rochelle, N. J.

Assistant Engineer on New Croton Aqueduct. (Entered Aqueduct Engineer Corps as Chainman, in February, 1885.)

MCKINLEY, WM. BRADFORD, E. M., ... 1895.
Care Wm. Jarvis, Tumaco, Rep. Colombia, S. America.

Assistant at Pelican-Pines Mine, Georgetown, Colo., Oct.-Dec., 1895. Mine Clerk at Peerless Coal Mine, Aguilar, Colo., Dec., 1895 to Feb., 1896, General Assay Office at La Belle, Taos Co., New Mexico, May to Nov., 1896. March, 1897, Assistant Engineer Playa de Ore Mining Co., Ecuador, S. A.

MCLAUGHLIN, CHARLES SWAIN, PH. B., . . . 1884.
874 Broadway, and 2041 Fifth Avenue, New York City.

MACKAYE, HAROLD STEELE, C. E., ... 1887.
45 Broadway and 201 W. 106th St., New York City.

Three months' work in New York Harbor in Army Corps of Engineers. One year's employment in the Office of Patent Solicitors. 1889–92, acting as Fourth Assistant Examiner of the U. S. Patent Office. Since July, 1892, Patent Counsel for Westinghouse Electric and Manufacturing Company.

MacTeague, John Joseph, E. M., ... 1883.
Address unknown.

Maclay, James, C. E., ... 1888.
Tutor in Mathematics, Columbia College, and 87 Union Street, Newark, N. J.

Mahony, Arthur Stuart, E. M., ... 1889.
51 W. Ninety-fourth Street, New York City.

1890, First Assistant General Manager of the New Birmingham Iron and Land Company. 1891, Treasurer of the same company, also Chemist to the Tassie Belle Furnace, New Birmingham, Texas. 1893, Contractor.

Malukoff, A. J., ... 1893.
39 Whiting St., Boston Highlands, Boston, Mass.

Mannheim, Hermann Charles, E. M., ... 1887.
Mail returned. Care of R. A. Parker, Johannesburg, S. A. R., South Africa.

Mannheim, Paul August Louil, E. M., ... 1885.
United Smelting and Refining Company, East Helena, Montana.

Marie, Leon, E. M., ... 1885.
152 West Eighty-sixth Street, New York City.

Marsh, John Rollin, E. M., ... 1887
Address unknown.

1887, Chief Engineer, Indiana Bridge Company.

Martin, Edward Ward (Associate), ... 1877.
Chemist, Board of Health, 301 Mott Street, New York City.

Massa, Charles Griswold, C. E., ... 1889.
Fort Lee, N. Y.

Since October, 1889, on varied engineering work, including: Topographical Survey, Greenwood Lake, N. Y., 1889; Structural Steel Shop Inspection with R. W. Hildreth & Co., at Phœnixville, Pa., 1890, and at Harrisburg, Pa., 1894; Construction Lehigh Valley Ry. Extension, Geneva, N. Y., 1890; Street Railway Construction, Allegheny, Pa., 1890–91; R. of W., Maintenance, Construction, Northwest System, Penna. Lines, 1891–93; Construction, Masonry, Dam, Etc., Newton, N. J., Water Works, 1895.

Massa, Louis Ferdinand, C. E., ... 1890.
136 Liberty Street, New York City, and Fort Lee, N. J.

October, 1890–92, shop practice, Maryland Steel Works, at Sparrow's Point, Md., as follows: October, 1890, to July, 1891, Machine-shop practice. July,

1891, to September, 1891, Bessemer Mill Construction. September, 1881, to September, 1892, Bessemer Rail-mill and Roll-house; Mechanical and Metallurgical Engineering. October, 1892–93, Post-graduate Electrical Engineer at Columbia College. February, 1894, to date, Electric Engineering, Construction and Constructing.

MASTERS, H. K., E. M., ... 1894.
Nichols Chemical Co., Laurel Hill, L. I., and 173 Congress Street, Brooklyn, N. Y.

MATHIS, THEOPHILUS SMITH, E. M., ... 1879.
Engineer of Mines, and U. S. Surveyor General's Office, and 529 East Street, Salt Lake City, Utah.

From January, 1890, to February, 1891, Assistant Draughtsman U. S. Surveyor General's Office, Salt Lake City, Utah. Since February, 1891, Chief Draughtsman of Mineral Division of said Office, and still holds that position.

MAYER, RALPH EDWARD, C. E., ... 1879.
Instructor in Mechanical Drawing, School of Mines, Columbia College, New York City.

MEISEL, F. C. A., PH. B., ... 1892.
Examiner Chemist, U. S. Laboratory, 402 Washington Street, New York City, and 44 Strong Place, Brooklyn, N. Y.

1892–93, 1st Asst. Chemist National Lead Co. 1893–94, Chemist, International Phosphate Co. 1895 to date, Examiner Chemist, U. S. Laboratory.

MEISSNER, CARL AUGUST, PH. B., ... 1880.
General Mgr. Londonderry Iron Co., Londonderry, Nova Scotia.

One year, assistant Chemist Joliet Steel Company. Three years, Chemist and Assistant Superintendent Brier Hill Iron and Coal Company, Youngstown, Ohio. One and a-half years, Head Chemist Joliet Steel Company. Three years, Manager Sterling Iron and R'wy Company, Sterlington, N. Y. At present, Vice-President and General Manager of the Vanderbilt Steel and Iron Company, Birmingham, Ala., after having personally organized this company. President Jefferson County Mining and Quarrying Company.

MELLISS, D. ERNETS, A. M., PH. D. (Associate), . . 1868.
Price's Building, 524 Sacramento Street, San Francisco, Cal.

Student regular course, three years, School of Mines. Afterwards, two and a-half years University of Goettingen, graduating Ph.D., in 1869. One year at University of Vienna. Since then, constantly occupied in civil and mining engineering. In 1873 was Chief Engineer in charge of Topographical and Geological Survey of Guanocaste and Nicoya for the Costa Rican Government. In 1881, Consulting Engineer to the Pacific Gas Light Company, of San Francisco, and in its interest studied the different gas-making systems in the United States, England, France and Belgium. Have made plans for and erected numerous gold, silver, copper and lead mines. Planned the Union Iron Works, of San Francisco, and superintended their construction; also the Arctic Oil Works and several other industrial establishments on the Pacific Coast. Designed and built the Mazatlán Water Works, in Mexico; the Hydraulic Press Brick Works, of California, the

largest establishment of its class on the Pacific Coast. Four years in Central America and Mexico. Was Administrator of San Josà de las Bocas and Consulting Engineer to Guadalupe de los Reyes, the most successful silver mine of Sinaloa. Now Copsulting Engineer in San Francisco, and particularly occupied in that capacity for the Olympic Salt Water Company, whose works are now being erected under his supervision and according to his plans.

MERRILL, FREDERICK JAMES HAMILTON, PH. B., PH. D., 1885.

State Museum, and 268 State Street, Albany, N. Y.

1885–87, Assistant on the Geological Survey of New Jersey. 1886–90, Fellow in Geology, Columbia University. 1890 to date, Assistant State Geologist and Assistant Director of the New York State Museum, Albany, N. Y.

MERRITT, JAMES HAVILAND, PH. B., A. M., . . . 1880.

3 Munro Place, Brooklyn, N. Y.

From 1881–88, Chemist to the Bradley White Lead Co. In 1889, entered the School of Mines as Post-Graduate in the course of Architecture. 1892–93, Architectural Study.

MERZ, EUGENE, E. M., ... 1892.

Box 216 and 143 Littleton Ave., Newark, N. J.

Assistant Superintendent American Ultra Marine Works.

MESEROLE, WALTER MONFORT, C. E., ... 1881.

189 Montague St., and 2789 Atlantic Avenue, Brooklyn, N. Y.

1881, Transitman and Topographer Continental Railway Co. 1881–83, Assist. Eng. in Construction, N. Y., West Shore and Buffalo Ry. 1884–85, Division Engineer Maintenance of Way ; 1885, Chief Engineer Catskill Mountains and Cairo Railway. 1885, in charge Topographical Survey for Kings County Charities' Commission. 1886 to date, in General Practice, located at Brooklyn, N. Y. Specialties : Improvement and Development of Real Estate and Surveying for Legal and Construction Purposes ; City Surveyor of the City of Brooklyn ; Chief Engineer South Brooklyn R. R. and Terminal Company, German-American Improvement Company and Hancock and State Line Railway Company.

MESSITER, E. H., C. E., ... 1894.

Arkansas Valley Smelting Co., Leadville, Colo.

1889, Draughtsman, New Croton Aqueduct. 1891 (Summer vacation), Draughtsman, Mfg. Investment Co., Madison, Me. Mill Construction, June, 1894, to November, 1894. Inspector under Wm. Barclay, Parsons, C. E. November, 1894, June, 1895, Engineer Guggenheim Smelting Co., Perth Amboy, N. J. June, 1895, to January, 1896, Chief of Party, Surveys for Rapid Transit Commission, N. Y. City. January, 1896, to November, 1896, Engineer Guggenheim Smelting Co., Perth Amboy, N. J. November, 1896, to April, 1897, Engineer Philadelphia Smelting & Refining Co., Pueblo, Colo. April, 1897, to date, Engineer Arkansas Valley Smelting Co., Leadville, Colo.

MEYER, HERMAN HENRY BERNARD, E. M., . . . 1885.

539 W. Twentieth Street, New York City, and *for Mail* 844 Putnam Avenue, Brooklyn, N. Y.

Surveying, Field and Office work at Pelham Park, Westchester Co., July to November, 1895. December, 1895, to date, Engineer for Oregon Iron Works, New York ; designing and erecting machinery for manufacturing illuminating gas.

MIDDETON, JOHN, C. E., ... 1887.
2789 Atlantic Avenue, and 14 Glenade Place, Brooklyn, N. Y.
1888 to date, Surveyor, Assistant to W. M. Meserole, C. E.

MILLER, CHARLES LEWIS, E. M., ... 1885.
Illinois Steel Company, 3179 Ashland Avenue, and 3609 Ellis Avenue, Chicago, Ill.
1886, Assistant Chemist Edgar Thomson Steel Works, Braddock, Pa. 1886–87, Chemist and Assistant Supt. Carbon Iron & Pipe Co., Parryville, Pa. 1887-90, Supt. The Missouri Furnace Co., St. Louis, Mo. 1890 to 1896, Supt. Blast Furnaces at Union Works of Illinois Steel Co., Chicago, Ill. Since August, 1896, Genl. Supt. Union Works, Ill. Steel Co., Chicago, Ill.

MILLER, CHARLES WATTS, E. M., ... 1884.
Box 401, Aspen, Colo.
1884–85, Metallurgical Engineer Hecla Bronze and Iron Works. 1885-86, Assayer and Chemist, Aspen, Colo. 1886–91, Mining Engineer and United States Deputy Mineral Surveyor, Aspen, Colo. General mining engineering business.

MILLER, EDMUND HOWD, PH. B., A. M. (1892), PH. D. (1894), ... 1891.
Tutor in Assaying, Columbia University, School of Mines, and West Nyack, Rockland Co., N. Y.
1892–1897, Tutor in Analytical Chemistry and Assaying, School of Mines.

MILLER, RUDOLPH PHILIP, C. E., ... 1888.
141 East Fortieth Street, New York City.
1888–1890, Assistant to E. M. W. 1890-94, Supervisor R. and D. Railway till April, 1894. August to November, 1894, with W. S. Miller, Builder, New York City. November, 1894, to October, 1895, with Long Island R. R. as transitman and assistant. December, 1895, to date, with Department of Buildings, New York City.

MILLER, SAMUEL O., C. E., ... 1895.
West Nyack, N. Y.
From June to September, 1895, field and office work for Ramapo Water Co. January to March, 1896, Engaged in Mine Surveying for the Sterling Iron and R. R. Co., Sterlington, N. Y. From March, 1896, to date, in the employ of the Department of Buildings of New York City.

MILLIKEN, GEORGE FANSHAWE, E. M., ... 1870.
Land Department, N. P. R. R., Tacoma, Wash., and Union League Club, New York City.
1879–80, Superintendent "Milton Mining Company." 1880-83, General Manager "Chester Mining Company." 1883-87, in General Consulting Practice as Engineer. 1887-90, General Manager "Costa Rica Mining Co., Ltd." 1890, to date, Consulting Engineer Northern Pacific Railroad.

MOLDEHNKE, RICHARD GEORGE GOTTLOB, E. M., PH.D., 1885.
McConway & Torley Co., Forty-eighth Street and A. V. R. R., and 164 Home Street, Pittsburgh, Pa.

1885–87, Three Summer seasons with United States Coast and Geodetic Survey, New York and Philadelphia Harbors and Cape Cod, Mass., *Hydrographic Work*, Triangulation, Levelling, etc. 1885–86, Winter, nine months, *Sanitary Engineering*, Inspector, etc., New York Association for Improvement of Condition of Poor. 1887–89, *Electrical Engineering*, five months Mining Engineer Sprague Electric Railway and Motor Co., seven months Mechanical Engineer Crocker-Wheeler Motor Co., five months experimenting on patents taken out. 1889, Manufacturing for myself. Specialty in Machinists' Tools. 1889–90, Professor Mechanical and Electrical Engineering, Michigan Mining School, Houghton, Mich. 1890, to date, Engineer McConway & Torley Co. Expert in Malleable Castings.

MONELL, JOSEPH THOMPSON, C. E., ... 1889.
136 Liberty St., and 236 W. Twenty-second St., New York City.
1891, Electrical Engineering, Curtis Electrical Mfg. Co. 1892, Tutor in Astronomy, Columbia College.

MONTENEGRO, MANUEL RAFAEL, E. M., ... 1890.
539 W. Twentieth Street, New York City, and 53 Washington Street, Hoboken, N. J.
1890, Spiral Weld Tube Company, East Orange, N. J., and studying machine-shop practice. 1891–92, engaged in the formation of mining companies. 1892 to date, Assistant Superintendent Oregon Iron Works, New York City.

MORA, MARIANO LUIS, C. E., ... 1891.
Genl. Elec. Co., Schenectady, N. Y.
Graduate Post-graduate Course Electrical Engineering, 1894.

MORAN, DANIEL EDWARD, C. E., ... 1884.
Sooysmith & Co., Mills Building, and 26 W. Eighteenth Street, New York City.

MORGAN, WILLIAM FELLOWES, A. B., E. M. (Life Member), 1884.
Brooklyn Bridge Freezing and Storage Co., Arch 4, Brooklyn Bridge, New York City, and Short Hills, N. J.
1884–88, Banking and Brokerage. 1888 to date, as above.

MOSELY, RICHARD KEELER, PH. B., ... 1889.
Architect, Room C, Produce Exchange Building, New York City, and 139 Glenwood Avenue, East Orange, N. J.
From June, 1889, to January, 1893, worked as Draughtsman in the Offices of S. J. O'Connor, Carrère & Hastings, and Richard M. Hunt, of New York, and Benj. Silliman, of Yonkers, N. Y. Since January, 1893, practicing Architecture independently at the above address.

MOSES, ALFRED JOSEPH, E. M., PH. D., ... 1882.
Adj. Professor Mineralogy, Columbia University School of Mines.
1882–85, Assistant in Mineralogy, School of Mines. 1885–90, Instructor in Mineralogy and Metallurgy. 1890 to 1897, Adjunct Professor of Mineralogy. Managing Editor SCHOOL OF MINES QUARTERLY.

MULFORD, ROBERT, E. M., ... 1884.
Mgr. Frazer & Chalmers, 80 Broadway, New York City, and 144 S. Second Avenue, Mt. Vernon, N. Y.

1890, Assistant Superintendent Rio del Oro Gold Co., Argentine Republic, S. A. 1891, Honduras? 1893, General Manager of The Kanimapoo Gold Mining Co., Limited, of Georgetown, Demerara, British Guiana, and am now in the employ of Frazer & Chalmers.

MÜLLER, GEORGE, PH. B., ... 1887.
634 East One Hundred and Thirty-ninth St., New York City.

1895, Chemist, Puget Sound Reduction Co., Everett, Washington.

MUNROE, HENRY SMITH, E. M., PH. D., ... 1869.
Professor Mining, Columbia College School of Mines, and 45 Sidney Place, Brooklyn, N. Y.

1869–70, Post-graduate Student in Chemistry and Economic Geology, School of Mines. 1870–71, Assistant Geologist Ohio State Geological Survey. 1870–72, Assistant Chemist, Department of Agriculture, Washington, D. C. 1872–75, Assistant Geologist and Mining Engineer, Geological Survey of Yeddo, Japan. 1875–76, Professor of Geology and Mining, University of Tokio, Japan. 1877–91, Adjunct Professor of Surveying and Practical Mining, and 1891, Professor of Mining, School of Mines, Columbia University, New York City. 1881–84, Manager, and 1890–92, Vice-President American Institute Mining Engineers.

MUNROE, OTIS MORTIMER, PH. B., ... 1879.
Banker, De Soto, Mo.

MUNSELL, CHARLES EDWARD, PH. B., PH. D., . . 1878.
F. W. Devoe & C. T. Raynolds Co., 110 Horatio Street, New York City, and Rye, N. Y.

November, 1878, with A. E. Foote, Mineral Dealer, Philadelphia. March 1879, with T. A. Edison, Menlo Park, N. J. May, 1879, Chemist, Bushwick Chemical Works, Brooklyn, N. Y. October, 1879, Stencilographer and Celestyper, School of Mines, N. Y. January, 1880, to December, 1885, Milk Inspector, New York City Health Department. July, 1881, to May, 1883, State Milk Inspector, New York State Board of Health. 1886 to 1895, Analyst and Assistant Chemist. F. W. Devoe and C. T. Raynolds Co., New York City. Specialty, Paints and Colors.

MURPHY, HENRY MORGAN, E. M., ... 1878.
Murphy Varnish Co., Chestnut and McWhorter Streets, Newark, N. J.

MURPHY, JOHN GLENVILLE, E. M., C. E., . . . 1877.
Grand Union Hotel, New York City.

Assistant Superintendent Orinoco Exploring and Mining Co., Gold Mine. Assistant Superintendent Callao Gold Mining Co. Territorial Geologist of Wyoming. Superintendent Esmeralda Mining Co., Black Hills, Dakota, Gold Mine, Superintendent New York and Lee Mountain Syndicate, Montana, Lead-Silver Mines. Has made professional examinations in nearly all parts of the United States, the Pachuca Silver and Jugnann Copper Districts in Mexico, and two and a half years ago made a six months' trip in Colombia and Ecuador.

N.

NAVARRO, JOHN ADALBERTO, C. E., ... 1880.
Seminario No. 1, Mexico City, Mexico, and care Mexican Consul General, 35 Broadway, New York City.

1881-82, Civil Engineering Course in Polytechnicum, Hanover, Germany. 1882-84, Mexican Government Commissioner to study railway systems of Europe. 1885-6, Railroad Inspector in Interoceanic Railroad, Mexico. 1886-87, Assistant Compiler of Memoir, published by Department of Public Works (*Fomento*), Mexico. 1887 to date, Engineer in charge of Surveys and Representative in Bhiapas of the Mexican Land and Colonization Co.

NEFTEL, KNIGHT, C. E., PH. D., ... 1879.
115 Broadway, New York City.

NESMITH, JAMES, E. M., ... 1879.
256 Henry Street, Brooklyn, N. Y.

NEWBERRY, SPENCER BAIRD, E. M., PH. D., . . . 1878.
The Sandusky Portland Cement Co., Sandusky, Ohio.

1878-92, Professor of Chemistry, Cornell University, Ithaca, N. Y.

NEWBERRY, WOLCOTT ELY, E. M., ... 1884.
Colorado Springs, Colorado.

1884-85, Metallurgist, Casa Grande Co., Arizona. 1885-86, Assistant Superintendent Cananea Mg. Co., Sonora, Mexico. 1886-87, Superintendent Argentum Mining Co., Aspen, Colo. 1887, General Manager Aspen Mg. and Smelting Co., Aspen, Colo. 1888 to present time, General Manager Enterprise Mg. Co., Aspen, Colo. Superintendent Aspen Contract Co., Aspen, Colo. Superintendent Mutual Benefit Milling and Mining Co., Aspen, Colo. 1892, General Manager Isabella Gold Mining Company, Cripple Creek, Colorado. 1893, as above. 1894, Mining Engineer, Colorado Springs. 1896, Mining Engineer, Examining Mines in South America.

NEWBROUGH, WILLIAM, A. B., E. M., ... 1884.
174 West One Hundred and Seventh Street, New York City.

NEWHOUSE, EDGAR LIEBER, E. M., ... 1886.
75 and 77 Worth Street, New York City.

NICHOLS, RALPH, E. M., C. E., ... 1877.
Superintendent, De La Mars, Nev. G. Mg. Co., Delamar, Lincoln Co., Nevada.

1878, Ore Sorter, Hukill Mine, Idaho Springs, Colo. Later, Assistant in F. E. Brown's Civil and Mining Engineering office, Georgetown, Colo. Later, Assayer and Chemist La Plata M. and S. Co., Leadville, Colo. Appointed U. S. Deputy Mineral Surveyor in 1879. 1879-82, Civil and Mining Engineer at Leadville, Colo., with following firms: Page, Nichols & Co., and Nichols & Dunham. Superintendent Farwell Cons. Mining Co.'s Gold Mill at Independence, Colo. Superintendent of the Big Pittsburg Cons. Mining Co., Leadville. 1883, Superintendent of the Viola Mining and Smelting Co. Later General Manager of same until 1891. Since then have been mining and working mines on lease. Examined

mines in Colorado, Idaho, Nevado, and Mexico. 1894, General Superintendent The Comstock Tunnel Co. Interested in mines in Colorado and Idaho, and am working mines in Idaho under lease. Have acted as ore buyer for the Cons. Kansas City S. and R. Co., and am at present representing the Globe S. and R. Co., in this State.

NOBLE, LOUIS SPENCER, E. M., ... 1885.
Address unknown.

1885–89, Mining Engineer to Iron-Silver Mg. Co., and Nisi Prius Cons. Mg. Co., of Leadville, Colo. Also during 1889 Consulting, Reporting and Lawsuit work on other Colorado properties. 1889–90, Superintendent of Mines and Mining Engineer to Constancia Mining and Smelting Co., at Sierra Mojada, Coahulia, Mexico. 1890–91, Mining Engineer on Lawsuit preparation, with Blue Bird Mining Co., Ltd., of Butte, Montana. Specialty, Lead, Silver and Gold Mines and Mining.

NOLAN, THOMAS, M. S., PH. B., ... 1884.
Nolan, Nolan & Stern, Architects, 1017 Chamber of Commerce Building, Rochester, N. Y.

NORRIS, DUDLEY HIRAM, E. M., ... 1877.
123 West Thirty-fourth Street, New York City.

NORRIS, ROBERT VAN ARSDALE, E. M., . . . 1885.
Assistant Engineer, P. R. R., Dept. of Anthracite Coal, Room 28 First National Bank Building, and 24 S. Franklin Street, Wilkesbarre, Pa.

1885, Assistant in Practical Mining and Surveying, School of Mines. U. S. Inspector of Dredging, in charge of Maurice River Improvement, Millville, N. J. 1886, Chemist, Herman Behr, Manufacturer of Colors, Brooklyn, N. Y. June, 1886, to date, Assistant Engineer, Pennsylvania Railroad Department of Anthracite Coal Collieries. Specialty, Mechanical Engineering of Collieries.

NORTON, LUCIEN HOLLEY, E. M., ... 1886.
Penna. Smelting Co., Sandy, Utah.

1887–1890, Engineering Office, N. Y., N. H. & W. R. R. Experience in Railroad Construction, Location and Preliminary Surveys, Office Work and General Surveying. 1890, Assayer and Engineer to West Indian New Gold Mining Corporation, San Domingo, West Indies. Experience in Free Melting of Gold ores, Assaying, Surveying, etc. January, 1891–92, Assayer for Daly Mining Co., Park City, Utah. Experience in Assaying, General Analyses. Also Leaching of Silver ores by the Russell Process. 1892 to date, as above.

NOYES, JAMES ATKINS, PH. B., A. B. (Harvard, '83),
(Life Member), ... 1878.
71 Sparks St., Cambridge, Mass.
Editor Quinquennial Catalogue, Harvard University.

NOYES, WILLIAM SKAATS, E. M., ... 1875.
Shafter, Presidio County, Texas, and 2023 Summit Street, Oakland, Cal.

1877–79, Assayer for McCrackin Mining Co., Mohave Co., Arizona. 1879–1881, Foreman of Bodie Mill, for Bodie Coal Mining Co., Bodie, Cal. 1881–1883, Examining Mines for San Francisco Capitalists. 1883 to present time, Superintendent of Presidio Mining Co., and The Cibilo Creek Mill and Mining Co., Shafter, Presidio Co., Texas.

NYE, ALVIN CROCKER, PH. B., ... 1884.

Hayden Furn. Co., 1 West Thirty-fourth St., and 107 E. Seventieth Street, New York City.

1884–85, Draughtsman, C. C. Haight, Architect, New York City. 1885–90, Designer and Head Draughtsman, Herter Brothers, New York City. 1890 to date, Furniture Designer and Architect, The Tiffany Glass Co., New York City. 1892, Chief Designer as above.

O.

O'CONNOR, MICHAEL JOSEPH, E. M., PH. B., . . 1881.

Little & O'Connor, Architect (1884), the Astor Court Building, 20 West Thirty-fourth Street, New York City.

O'CONNOR, THOMAS DEVLIN, PH. B., ... 1881.

O'Connor & Elliot, 16 Exchange Place, and 12 E. Forty-fourth Street, New York City.

OF, CHARLES, E. M., ... 1896.

892 Prospect Ave., New York City, N. Y.

OLCOTT, EBEN ERSKINE, E. M., ... 1874.

Mining and Metallurgical Engineer, 18 Broadway, and 38 W. Thirty-ninth Street, New York City.

1874–75, Chemist to Ore-Knob Copper Co., in charge of Hunt & Douglas Process. 1875–76, Assistant Supt. Penna. Lead Co.'s Works, Mansfield Valley, Pa. 1876–78, Assistant Supt. Orinoco Exploring and Mining Co., at their Gold Mines in Venezuela. 1878–79, Supt. of the same. 1879–81, Examining Mines in Colorado, Utah, Nevada and California, for New York Investors. 1881–85, Supt. St. Helena Gold Mines, Sonora, Mexico. 1885, opened office in New York as Consulting Engineer, and since then has been engaged as Consulting Mining and Metallurgical Engineer, in Peru, Republic of Colombia, Dutch and British Guiana, Mexico, British Columbia, Ontario, New Brunswick, and the United States. 1895, Consulting Mining and Engineer and Genl. Mgr. Hudson River Day Line. Member of firm Olcott, Fearn & Peele Consulting Mining Engineers.

ORMSBEE, JAMES JACKSON, E. M., ... 1886.

Superintendent Tenn. Coal, Iron & Ry. Co., Henry Ellen, Ala.

1886–91, Mining Engineer of Tracy City Division of Tennessee Coal, Iron and Railroad Co. 1891–92, Superintendent, Thomas Coal Mines, of Tennessee Coal, Iron and Railroad Co., Whitwell, Tenn. 1892–94, Engineer and Superintendent Sequachee Valley Coal and Coke Co. 1894, Superintendent Poplar Creek Div. Tenn. Coal, Iron and Railroad Co.

OSTERBERG, MAX, E. E., A. M., ... 1894.

27 Thames Street, and 113 East Sixty-fifth Street, New York City.

Summer '94, after graduation: Editor of the *Proceedings* of the Chicago Electrical Congress. Practical shopwork in a dynamo factory. October 1st, Appointed Associate Editor of *Electric Power*. During season '94-95, Instructor of Electrical Engineering at the National School of Electricity, at the Y. M. C. A. in New York City and Stamford, Conn. Fall '94, Reëntered College to pursue post-graduate studies. June '95, was appointed University Fellow in Mechanics. January, '96, Author of "*Synopsis of Current Electrical Literature.*" Established as Consulting Engineer and Electrical Expert on Sept. 1, '96.

OSTERHELD, THEODORE W., E. M., ... 1886.

Consulting Eng., Apartado, No. 38c, Puebla, Mexico.

Assistant Superintendent of Blast furnaces, P. S. Co., 1886–87. General Foundry Practice, Worthington P. Works, 1887–88. Owner of Foundry and General Iron Works, 1888–89. Vice-President, Pendleton Mining Co., and Consulting Engineer, 1889, '90, '91, and General Consulting Engineer, Iron and Coal Specialty, and Metallurgist of Iron and Finished Manufacturing. Interval of 1880-91, of the months December to May, Superintending Construction of Rolling Mill, Southwest Virginia. Specialty, Coal and Iron of the Virginias. President of the Southern Reducing Co., Experts, Chemists and Mining Engineers. Locating Engineer, C. & M. R. R., Cartagena, '91-92; Chief Engineer, C. & Z. R. R., '93–94–95, Coabguila, Mexico. '95 to present date, Consulting Engineer and Member of the Banking Firm, Rossi, Headen & Co., Puebla, Mexico.

OWEN, FREDERICK NASH, E. M., ... 1878.

Civil and Sanitary Engineer, 115 East Forty-fifth Street, New York City.

P.

PAGE, GEORGE STEPHEN, E. M., ... 1885.

Care of Park Bros. & Co., Limited, Pittsburgh, Pa.

1885–86, Assistant Chemist Edgar Thompson Steel Works. From July, 1886, to date, Manager of Steel Works with Park Bro. & Co., Ltd. Specialty: Manufacture of Open-Hearth and Crucible Steel.

PAGE, WILLIAM STEVENS, E. M., ... 1882.

Aqueduct Commission, Sing Sing, N. Y.

PAINTER, CHARLES ALBERT, E. M., ... 1884.

J. Painter & Sons, Pittsburg, Pa., and 208 Western Avenue, Allegheny City, Pa.

PAINTER, GEORGE EDWARDS, PH. B., ... 1883.

J. Painter & Sons Co., Pittsburg, Pa., and 212 Western Avenue, Allegheny City, Pa.

PARKER, ANDREW MCCLEAN, E. M., ... 1880.

Acting 1st Assistant Engineer, Dept. of Docks, Pier A, and 35 W. One Hundred and Nineteenth Street, New York City.

PARKER, HERSCHEL CLIFFORD, PH. B., ... 1890.

Dept. of Physics, Columbia University, New York City, and 21 Ft. Green Place, Brooklyn, N. Y.

1890–91, Fellow in Physics, Assistant Instructor, Course in Physical Measurements. 1891–93, Assistant. 1893–97, Tutor in Physics. Instructor in Electrical Measurements.

PARKER, RICHARD ALEXANDER, C. E., E. M., . . 1878.
Consulting Mining Engineers, 403 Lyceum Bldg., Duluth, Minn., and East Ohio Street, Marquette, Mich.

1878–79, Assistant Superintendent, Montezuma Silver Mining Co., Montezuma, Colo. 1880–81, Surveyor at Georgetown. 1881–82, Chief Draughtsman, Mexican Natl. Cons. Co., Laredo, Texas. 1883–84, Examining Mines in Colorado, Utah and Idaho mainly. 1885–86, Superintendent, Atlanta Hill Gold Co. Also Superintendent of the Big Lode (Gold) Co., Atlanta, Alturas Co., Idaho. 1887 to date, Resident Manager and Agent for Samson Iron Co., Imperial Iron Co., and Barasa Iron Co. Also Consulting Mining Engineer. Specialties, Gold and Silver Mining and Milling, and Iron ores.

PARKS, JOHN RANDOLPH, E. M., ... 1880.
Helena, Mont.
Consulting Mining Engineer.

PARRAGA, CHARLES FREDERICK, C. E. (Life Member), . 1883.
58 William Street, and 145 W. Ninety-seventh Street, New York City.

1883–84, Inspector of Construction of Bridges and Railroad Material in Europe. 1884–86, Railroad Engineer in Colombia, S. A. 1887 to date, General Expert Business. 1891, Delegate from Colombia to the Inter-Continental Railway Commission at Washington, D. C.

PARROT, EDWARD MONROE, E. M., ... 1870.
Ontario, Wayne County, N. Y.

PARSONS, HENRY, C. E., ... 1888.
Secy. and Treas. So. Ca. & G. R. R., 15 Broad St., and 1033 Madison Avenue, New York City.

PARSONS, WILLIAM BARCLAY, A. B., C. E., . . . 1882.
22 William Street, and 51 East Fifty-third Street, New York City.

Previous to graduation served as Assistant Engineer Arnot and Pine Creek Railroad and Blossburg Coal Mine. After graduation entered Maintenance of Way Department of the New York, Lake Erie and Western Railroad. Resigned in 1885 and commenced practice as Consulting Engineer, New York, as such have had charge of much heavy engineering construction. At present Chief Engineer Rapid Transit Commission, New York City.

PAYNE, CLARENCE QUINTARD, E. M., ... 1882.
President Payne Separator Co., 9 Cliff Street, New York City, and Stamford, Conn.

PEARIS, CHARLES FOWLER, E. M., ... 1884.
Box 374, Helena, Mont.

PECK, STAUNTON BLOODGOOD, C. E., E. M., . . . 1886.
Link Belt Machinery Co., Thirty-ninth Street and Stewart Avenue, Chicago, Ill., and 111 East Thirty-fourth Street, New York City.

One and a half years Mechanical Engineer, Burr & Dodge, Philadelphia. Two years Assistant Chief Engineer Link Belt Engineering Company, Philadelphia. Since 1888, Assistant Chief Engineer Dodge Coal Storage Company. Since 1890 and at present, Chief Engineer Link Belt Machinery Company, Chicago. Specialty, handling materials in bulk or package and power transmissions.

PEELE, ROBERT, E. M., ... 1883.
"The Monterey," One Hundred and Fourteenth Street, and Morningside Park, New York City.

1883, Assayer, Designolle Reduction Works, Charlotte, North Carolina. 1883–84, Assayer and Assistant Sup't Silver-King Mining and Milling Co., Montezuma, Colorado. 1884–86, Foreman, Dry-crushing and Amalgamating Silver-mill, Silver-King Mining Co., Pinal, Arizona. 1886, went to England to examine systems of Sewage disposal used in inland towns. 1887, Professional work as assistant, in New York and Arizona. 1888, Examining gold-mines in Republic of Colombia, S. A. Supt. Mudsill Mining Co., Ltd., Fairplay, Colorado. Examinations and Ore-testing on Copper and Tin Properties, New Mexico and North Carolina. 1889, Examining Gold placers, Dutch Guiana, South America. 1889–90, Supt. Oregon Gold-mining Co., Cornucopia, Oregon. 1890–92, Examining Silver-, Tin-, and Gold-mines in Peru, Bolivia, and Republic of Colombia, S. A., for the Peruvian Exploration Syndicate, Ltd., London, and Lima, Peru. 1892, Adjunct Prof. of Mining, School of Mines, Columbia College.

PELLEW, CHARLES ERNEST, E. M., ... 1884.
College Physicians and Surgeons, 437 West Fifty-ninth Street, and 51 East Fifty-fourth Street, New York City.

1884–85, studied chemistry at Lehigh University and Bethlehem Steel Works. 1885–87, studied chemistry, physics, microscopy and bacteria at School of Mines and at College Physicians and Surgeons. Private Assistant to Professor Chandler. 1887 to date, Instructor and, later, Demonstrator in Physics and Chemistry at College Physicians and Surgeons. Hon. Fellow in Applied Chemistry, School of Mines. Also in general chemical practice with Professor Chandler (as partner). Specialty, chemical and other expert work, including medical and sanitary questions, *e. g.*, toxicology. Also as patent expert in chemical and physical subjects.

PENGNET, CHARLES PAUL, C. E., ... 1895.
231 West Forty-fifth Street, New York City, N. Y.

PENNINGTON, JOSEPH POPE, A. M. (Associate), . . 1868.
Morristown, N. J.

1881–83, Assistant Engineer E. T. V. & G. R. R., 1883–84 Engineer Tombstone Mill and Mining Co., 1885–93, railroad construction with general contractors. Assistant Secretary, Louisville, St. Louis and Texas Railway. Resigned August, 1893. Previous responsibilities as actuary in connection with life insurance interests.

PERRINE, GEORGE, C. E., ... 1894.
22 William Street and 716 West End Avenue, New York City, N. Y.

With Chief Engineer Rapid Transit Commission, N. Y. City, since graduatnig.

PERKINS, THOMAS SLADE, PH. B., ... 1888.
Ninth Street and Gowanus Canal, South Brooklyn, and 39 Garden Place, Brooklyn, N. Y.
1889 to date, New York Tartar Company.

PIERCE, FREDERICK EMERY, C. E., ... 1892.
Dept. of City Works, Room 49 Municipal Bldg., and 71 Columbia Heights, Brooklyn, N. Y.
1892, Learner in Bessemer Mill, Maryland Steel Co., Sparrow's Pt., Maryland. 1893, Draughtsman, New Jersey Steel and Iron Co., Cooper, Hewitt & Co., New York City. Trenton, N. J. 1895, P. R. R. Engineer in corps of Principal Assistant Engineer at Jersey City. 1895–97, Engineer-draughtsman, Wallabout Improvement Dept. of City Works, Brooklyn.

PIEZ, CHARLES, E. M., ... 1889.
Chief Engineer Link Belt Engineering Co., Nicetown, and 3124 North Broad St., Philadelphia, Pa.
1889–91, Draftsman with the L. B. E. Co. 1891–92, Assistant Chief Engineer L. B. E. Co. Since 1892, Chief Engineer of the L. B. E. Co., and the Dodge Coal Storage Company, Philadelphia.

PINKHAM, HERBERT, C. E., ... 1895.
Office Prin. Asst. Eng. Pa. R. R. Co., Jersey City, N. J., and 176 W. 81st Street, New York City.
1895 to date, in Engineer Corps, Principal Assistant Engineer, U. R. Rds. of N. J. Div., Penna. R. R.

PISTOR, WILLIAM, E. M., ... 1868.
Architect, No. 1 Madison Avenue, New York City.

PITKIN, LUCIUS, A. B., PH. B., ... 1881.
138 Pearl Street, New York City.
1881–85, Chemist to Laurel Hill Chemical Works, of Nichols Chemical Company, heavy chemicals, especially sulphuric acid. 1885 to date, Analytical and consulting Chemist, at above address. Specialty in consulting. Manufacture of acids and heavy chemicals, treatment of pyrites and copper smelting. Analytical work. General but special experience in argentiferous and auriferous copper ores and products. Microscopical and experimental investigations.

POLLEDO, YSIDOSO YGNACIO, E. M., ... 1885.
Address unknown.
1885, Assistant Engineer, Survey for Water-Works for city of Santiago de Cuba. 1886–89, Assistant Engineer and Principal Assistant Engineer in charge of track and structures, Cárdenas and Júcuro R. R., Cárdenas. 1889–1890, Manager of Santa Barbara Sugar Plantation, Baró. 1894-95, General Manager Cárdenas Sugar Refining, Cárdenas.

PORTER, H. HOBART, JR., E. M., ... 1886.
Westinghouse Electric and Mfg. Co., 120 Broadway, New York City, and Lawrence, L. I., N. Y.

1886-87, Fellow in Geology, School of Mines, Columbia University. 1887-88, Surveyor and Assayer Mexican Ore Company, Sierra Mojada, Mexico. 1888-89, Assistant Mining Engineer, Batopilas Mining Company, Batopilas, Mexico. 1889-90, Surveyor and Assayer, Duquesne Mining Co.; Assistant Superintendent, Ray & Poorman mine examinations, same company; Assistant Superintendent Sierrita County, Arizona, same company. 1890-91, Engineer with C. W. Hunt Company. 1891 to date, Westinghouse Electric and Mfg. Co. Member of firm of Sanderson & Porter, Engineers and Contractors.

PORTER, JOHN BONSALL, E. M., PH. D., . . . 1882.
Prof. of Mining and Metl'gy., McGill University, Montreal, Canada.

Assistant Engineer and Expert in tests of metals for various railways and corporations. Lecturer of Mechanical Engineering and Metallurgy in University of Cincinnati for some years. At present, and for several years past, Engineer Maintenance of Way, C. H. & D. R. R. system. Headquarters, Cincinnati, O. Chemical Engineer Proctor-Gamble Co., Ivorydale, O.

POST, ABRAM SKIDMORE, C. E., ... 1884.
173 Madison Avenue, New York City.

POTTER, WILLIAM BLEECKER, A. B., E. M., . . . 1869.
Consulting Mining Engineer, 1225–1227 Spruce St., St. Louis, Mo.

Professor Metallurgy and Mineralogy, Washington University, St. Louis, Mo., to 1893.

POWELL, FREDERICK, A. B., E. M., ... 1883.
Room 96 Kemble Bldg., Whitehall St., New York City.

1883-84, Mechanical Draughtsman and Engineer. 1885, Assayer at Duluth, Examination and Reports on Mineral Deposits in northeastern Minnesota and Canada, Assayer and Manager for Sentinel Gold Mining Co. of Minneapolis and Colorado. 1886 to 1888, Superintendent and Manager in Colorado for Denbigh Mining Co., of New York. 1888-92, Miscellaneous Surveying. 1893, Engineer for Charlotte Mineral and Mining Co., Charlotte, N. C. Examining and Reporting on Mines in North Carolina. June, 1894, to 1896, Mining Engineer, Charlotte, N. C.

POWERS, LEWIS J., JR., E. M., ... 1884.
Connecticut River Paper Company, Holyoke, and Springfield, Mass.

1885, Superintendent Vermont Construction Company, St. Albans, Vt. 1886, Superintendent Standard Pulp Company, Springfield, Mass. 1887-88, Assistant Superintendent Union Paper Manufacturing Company, Holyoke, Mass. 1888 to date, Agent Connecticut River Paper Company, Holyoke, Mass.

PRESTON, WILLIAM EVAN, C. E., ... 1889.
Foot E. Ninety-second Street and 980 Trinity Avenue, New York City.

1889 to date, submarine blasting and dredging for U. S. harbor work with grapple, divers and centrifugal pump.

PRINCE, JOHN L., E. E., ... 1894.
Edison Elec. Ill. Co., of New York, 53 Duane Street, New York City and 868 Flatbush Avenue, Brooklyn, N. Y.

Summer of 1894, Electric Light Station of the Flatbush Gas Co., Flatbush, L. I. Fall of 1894, with the General Electric Co. installing plant for the Bridgeport Traction Co., Bridgeport, Conn. Spring of 1895, in the Department of Public Works, Brooklyn, N. Y. October, 1895. to date, Inspection Department of the Edison Electric Illuminating Co., of N. J.

PROSSER, HERMAN A., E. M., ... 1896.
406 Stuyvesant Avenue, Brooklyn, N. Y.

Summer of 1896, Assistant Engineer Northwestern Mining & Exchange Co., Pa. 1896-97, Electrical Engineering course at Columbia.

PROVOST, ANDREW JACKSON, JR., C. E., . . . 1889.
Municipal Building, and 401 Washington Avenue, Brooklyn, New York.

1889 to 1894, Assistant Engineer in Sewage Construction, Department City Works, Brooklyn, N. Y. 1894-96, Engineer in charge Sewerage design, Dept. City Works, Brooklyn, New York. 1896-97, Secretary Brooklyn Engineers' Club, Consulting Engineer, Columbian Colliery Company.

R.

RANDOLPH, JOHN COOPER F., A. B., A. M., E. M., . 1869.
Consulting Mining Engineer, Mills Building, 15 Broad Street, New York City.

RANDOLPH, JAMES FITZ, B. S., E. M., ... 1876.
64 Madison Avenue, Morristown, N. J.

RAYMOND, ROBERT MATTHEW, A. B., E. M., . . . 1880.
Kalgoorlie, West Australia.

1880-82, Assistant Assayer, State of Maine Assay Office, Portland, Me. 1882-86, Assayer and Assistant Superintendent, Haile Gold Mine, S. C. 1883-89, School of Mines. 1889-90, Assayer and afterwards Assistant Superintendent, Montana Smelting Co., Great Falls, Mont. 1891, Superintendent, The Diamond Mining Co., Neihart, Mont. 1894, General Manager Harqua Hala Gold Mining Co., Harqua Hala, Ariz. 1896-97, General Manager Harqua Hala Gold Mining Co., Ltd., Arizona and West Australia. General Manager Brownhill Proprietary Gold Mines, Ltd., and Representative Mines Selection Co., Ltd.

RAYNOR, RUSSELL, PH. B., ... 1889.
Criminal Court Building, and 114 E. Forty-fifth Street, New York City.

Sept., 1889, to Aug., 1891, Chemist, with Martin Kalbfleisch Sons Co. Sept., 1891, to April, 1892, Assistant Chemist, Barber Asphalt Co. May, 1892, to date, Assistant Chemist New York Health Department.

RECKHART, DANIEL WILLIAM, E. M. (Life Member), . 1884.
Prop. Independent Assay Office, Box 88 El Paso, Texas.

RECKHART, GEORGE FREDERICK, C. E., ... 1892.
Commonwealth Mining and Milling Co., Pearce, Cochise County, Arizona.

Member of "Southwestern Mining Association" (Incorporated). Surveyor and Assayer for Cia Minera La Aventurea, Sabinal, Estado de Chihuahua, Mexico, since September, 1894. From February, 1894, to August, 1894, was on Engineering Staff of South Shore Railroad Co., Ltd., of Nova Scotia, Canada. 1896, Manager, The Furners & Lewis Co., Pachuca, Estado de Hidalgo, Mexico. Since September, 1896, with Commonwealth M. and M. Co., Pearce, Arizona.

REED, SYLVANUS ALBERT, A. B., A. M., E. M. (Life Member), ... 1877.
Manager Tariff Association of New York (Fire Underwriters) 32 Nassau Street, New York City.

1878, Secretary to Assistant Commissioner General, Paris Exposition. 1879, Lectured on Chemistry. Reported on Mines in Colorado. 1880–84, Superintendent and part Proprietor, Sampling and Concentration Works in Colorado, and Reported on Mines there and in Idaho and in the South. 1886, Consulting Practice in New York, Patent Expert work and on Dredging in New York Harbor. 1886–91, Superintendent Inspection Department of Fire Insurance Co. (Commonwealth of New York). 1893, Expert for New Insurance Rating, Mercantile Section of Boston. May, 1893, appointed Manager Western Factory Insurance Association. Special Agent Western Department of Continental Insurance Co. 1894, Manager Tariff Association Fire Underwriters, New York City.

REES, JOHN KROM, PH. D., A. B., A. M., E. M. (Life Member), ... 1875.
Professor of Astronomy and Director of Observatory, Columbia University, and 1 West Seventy-second Street, New York City.

A. M., 1875. E. M., 1875. Assistant in Mathematics, School of Mines, 1873–76. Professor of Mathematics and Astronomy, Washington University, St. Louis, Mo., 1876-81, Director of the Observatory, Columbia University, 1881. Instructor in Geodesy and Practical Astronomy, Columbia University, 1881–82. Professor of Astronomy, 1892. Chairman Board of Editors, SCHOOL OF MINES QUARTERLY, 1883–90. Vice-President New York Mathematical Society, 1891. Chairman of section on Astronomy and Physics of New York Academy of Sciences, 1891–92. Secretary of American Metrological Society, 1882. Fellow of Royal Astronomical Society of London, 1892. Member of the Astronomishe Gesellschaft, 1893. President of New York Academy of Sciences, 1894–95. Chairman Section on Astronomy and Physics of N. Y. A. S., 1891–94. Sec. Y. Am. Met. Soc., 1882. President N. Y. A. Sci., 1894–97.

RENAULT, GEORGE, C. E., ... 1883.
122 E. Nineteenth Street, New York City.

RESTREPO, CAMILO CLAUDIO, E. M., C. E., . . . 1887.
Medellin, Republic of Colombia, S. A.

RHODES, FRANCIS BELL FORSYTH, E. M., . . . 1874.
National S. & R. Co., South Chicago, Ill., and Quebec, Canada.

May, 1875, to December, 1876, Surveying Corps, Coxe Bros., Drifton, Pa. January, 1877, to May, 1878, Assistant Superintendent, South American Mining Co., Venezuela. November, 1878, to June, 1879, Working at Lead Mine, Canada. October, 1879, to April, 1880, Laborer, Ontario Mill, Park City, Utah. April, 1880, to July, 1881, Assistant Superintendent, Minge Furnace Co., Utah. August, 1881, to January, 1882, Assistant Superintendent St. Helena Mine, Sonora, Mexico. January, 1882, to April, 1883, Assistant Superintendent, Tombstone, M. and M. Co., Arizona. May, 1883, to December, 1883, Superintendent, Ramsham Smelting Furnace, Idaho. January, 1884, to May, 1885, Assistant Superintendent, Minge Furnace Co., Utah. June, 1885, to December, 1885, Foreman of Blast-Furnace Department, Kansas City S. and R. Co. October, 1886, to December, 1889, Superintendent, Chicago Works, Chicago and Aurora S. and R. Co. January, 1890, to date, Superintendent National S. and R. Co., South Chicago.

RHODES, ROBERT DUNN, E. M., ... 1879.
Arkansas Valley Smelting Works, Leadville, Colo., and Box 726, Quebec, Canada.

1879–80, Foreman, Germania Smelting Co., Salt Lake City. 1880–82, Night Foreman, Ontario Silver Mining Co., Park City, Utah. 1882–83, Superintendent, Tombstone, M. and M. Co. Reduction Works, Charleston. 1883–84, Mill Foreman, St. Helena Gold and Silver Mine, Sonora. 1884–85, Assistant Superintendent, Billing Smelter, New Mexico. 1885–86, Assistant Superintendent, Viola M. and S. Co., Idaho. 1887–88, Assistant Superintendent, Anglo-Mexican Mining Co., Yedras, Mexico. 1889–91, General Superintendent, Duquesne M. and R. Co., and Sierrita County, Arizona. 1891–92, Engineer, Frazer and Chalmers, City of Mexico. 1892–94, Supt. as above.

RICE, GEORGE SAMUEL, JR., E. M., ... 1887.
119 S. Market Street, and 432 N. Court Street, Ottumwa, Iowa.

1887, Assistant Field Engineer, Colorado & Utah Railway. 1888–89, Assistant Mining Engineer of Colorado Fuel Co. 1890 to date, Mining Engineer of Whitebreast Fuel Co.

RICH, JACOB MONROE, E. M., C. E. (Life Member), . 1883.
50 W. Thirty-eighth Street, New York City.

Pursuing further studies since graduation.

RICHARDSON, JOHN CLARENCE, E. M., C. E., . . . 1883
Address unknown.

RICKETTS, PIERRE DE PEYSTER, E. M., PH. D., . . 1871.
Professor, Analytical Chemistry, Columbia University School of Mines, and 115 E. Seventy-ninth Street, New York City.

1868, Assistant, General Chemistry, Columbia University. 1871–72, Assistant in Mineralogy and Metallurgy, School of Mines. 1872–75, Assistant in Assaying, School of Mines. 1875–86, Instructor in Assaying, School of Mines. 1886 to date, Professor of Assaying, School of Mines. Since graduation also engaged in general Metallurgical, Chemical and Mining Engineering work.

RIDSDALE, THOMAS WEDDLE, E. M., ... 1883.
Ridsdale & Lewis, 39–41 Cortlandt Street, New York City.

Assistant Superintendent of the Ruby Durango Mine, and Wilder-Macdonald Concentrating Mill to 1884. Superintendent of the Wilder-Macdonald Mill, 1884. From 1888 with the Worthington Pumping Engine Co. From June, 1889, as Secretary of the Company.

RIES, HEINRICH, PH. B., A. M., PH. D., . . . 1892.
Assistant in Mineralogy, School of Mines, Columbia University, and 28 W. 128th Street, New York City.

Summer of 1891 and 1892, on New York Geological Survey. October 1892, to August 1, 1893, Assistant Director, New York Scientific Exhibit, at World's Fair. July 1, 1893, to July 1, 1895, Fellow in Mineralogy, Columbia University. Asst. Geologist, N. Y. Geol. Survey, summer of 1895. Lecturer in New York City Public Schools, 1895–1897. Judge of Clays, Cotton States and International Exposition, October, 1896. Clay Specialist, U. S. Geological Survey, 1895 to date. In connection with this work am engaged in a study of the clays of the various states.

RODENBURG, CHAS., C. E., ... 1896.
428 W. Forty-fourth Street, New York City.

Summer 1896, Asst. at Summer School of Geodesy, Columbia University.

ROESER, FREDERICK, B. S., E. M., ... 1884.
240 West 130th Street, New York City.

ROGERS, OSCAR LEGARE, PH. B. (Arch.), . . . 1889.
125 W. Eighty-fifth Street, New York City.

1889–92, in Europe. 1893, Architect. 1894, in Europe.

ROLKER, CHARLES M., E. M. (Life Member), . . 1875.
6 Drapers Court, London, E. C., England.

1868–70, at Royal School of Mines, Clausthal, Germany. 1871–72, Working practically in Iron Mines of Hibernia and Mt. Pleasant, N. J., Wisconsin Lead Mines and Iron Mines of Lake Superior. 1872–75, at School of Mines, Columbia College. 1876, Assayer at Allouez Copper-dressing Works, Lake Superior. 1877, Mining Engineer to the Mariposo Land and Mining Co., Mariposo Co., Cal. (Gold). 1878, Superintendent, Brooklyn Company, Washoe Co., Nevada (Base Metal). 1879, Superintendent, Stormont Silver Co., Silver Reef (Silver). 1880–82, General Manager, Chrysolite S. Mfg. Co., Leadville, Colo. (Lead Carbonates). Since then to date, in General Consulting Practice as Mining Engineer and Metallurgist, Examining Mines, Mills and Placers in the United States, Old Mexico, Central America, South America and East Indies. Specialty, Precious and Base Metals other than Iron. 1891–92, Cons. Engr. to the British South African Company in its sphere south of Zambesi. 1894, Practicing, Consulting Mining Engineer. 1895–96, Manager Mining and Financial Trust Synd., London.

ROSENTHAL, ALBERT, C. E., ... 1892.
158 East Seventy-ninth Street, New York City.

ROWLAND, CHARLES BRADLEY, C. E., ... 1884.
Continental Iron Works, Greenpoint, Brooklyn, N. Y., and 329 Madison Avenue, New York City.

ROWLAND, GEORGE, C. E., ... 1887.
Continental Iron Works, Greenpoint, Brooklyn, N. Y., and 329 Madison Avenue, New York City.

RUPP, PHILIP, PH. B., M. D., ... 1884.
334 East 17th Street, New York City.
1884–87, Student of Medicine, College of Physicians and Surgeons, N. Y. 1887–88, House Physician and House Surgeon, St. Francis Hospital, N. Y. 1888 to date, Practicing Physician.

RUTHERFORD, F. M., E. M., ... 1879.
46 East 64th Street, New York City, N. Y.
Engineer M. of W. R. and D. R. R. till 1894. 1895 to date 2d Deputy Supt. Dept. of Buildings, New York City.

RUTTMANN, FERDINAND, JR., E. M., ... 1880.
35 Broadway, New York City.

RYON, AUGUSTUS MEADER, E. M., ... 1886.
E. 13 Produce Exchange, New York City.
1886–87, Assistant Engineer on New London Water Works. Assistant in Metallurgy, School of Mines, Columbia University. 1887–88, Assistant to F. N. Owen, Civil and Sanitary Engineer, New York City. 1888–91, Professor of Engineering and Mining, School of Mines, College of Montana, Deer Lodge, Mont. 1892 to 1895, President and Professor of Engineering, Montana College of Agricultural and Mechanical Arts, Bozeman, Montana. 1894, Irrigation Engineering for Agricultural Experiment Station. 1895, Prof. of Engineering, College of Agr. and Mech. Arts, Bozeman, Montana.

S.

SAGE, EDWARD EUGENE, C. E. (Life Member), . . 1877.
United States Assay Office, 30 Wall Street, New York City, and 77 Hillside Avenue, Orange, N. J.
I have been connected with this office since February, 1879, and have consequently no outside experience except in electricity, being President of the Essex County Electric Co., of Orange, N. J., and in Analytical Chemistry.

SANDS, FERDINAND, A. B., PH. B., ... 1882.
Drugs and Assaying Supplies, Box 1172, Butte, Mont.

SCHERMERHORN, FREDERICK AUGUSTUS, E. M. (Life Member), ... 1868.
41 Liberty Street, and 61 University Place, New York City.

SCHIEFFELIN, WILLIAM JAY, PH. B., PH. D. (Munich). . 1887.
Schieffelin & Co., 170 William Street, and 35 West Fifty-seventh Street, New York City.

SCHNEIDER, ALBERT FRANCIS, E. M., C. E. (Life Member), ... 1876.
Perth Amboy, N. J.

1876–77, In Europe visiting Smelting and Dressing Works. 1878, Chemist and Assayer Germania S. and R. Co., Salt Lake City, Utah. 1879, Foreman, Assistant and Superintendent Germania S. and R. Co., Salt Lake City. 1880–'83, Superintendent Germania S. and R. Co., Salt Lake City, Utah. 1883–'85, Superintendent G. Billing Smelting Works, Socorro, N. M. 1885–87, Superintendent Kansas City S. and R. Co., Argentine, Kansas. 1887, Connected with the Rio Grande S. Co., Socorro, N. M. 1887 to 1893, General Manager St. Louis S. and R. Co., St. Louis, Mo. Superintendent Great National Smelting Co., Monterey, Mexico, 1895.

SCHROEDER, J. LANGDON, C. E., ... 1889.
Member of the firm of Parrish & Schroeder, Architects, 1 Madison Avenue, and 50 West 11th Street, New York City.

July, 1890, to January, 1894, with Renwick, Aspenwall & Renwick, New York City, Architectural Draughtsman.

SCHROTER, GEORGE AUSTIN, E. M., ... 1893.
Box 877, Denver, Colo.

Superintendent Keystone and Manager Logan Group Mines, Colorado. Chemist Denver White Lead Works, February–August, 1894. Supt. of Rico Smelting and Ref. Co., Rico, Colorado, June, '93, to December, '95.

SCHUMANN, CHARLES HENRY, C. E., ... 1888.
Small & Schumann, 265 Broadway, and 21 East 99th Street, New York City.

1888, May, 1890, Assistant Engineer Chesapeake and Ohio Railway Co., Cincinnati, charge of Real Estate, Right of Way and Track and Construction work. May to August, 1890, Assistant Engineer to H. Alber, C. E., Birmingham, Ala., General Engineering. August, 1890, to March, 1891, Assistant Engineer Chesapeake and Ohio Railway Co., charge of subdivision of Town of West Clifton Forge, Va., and Right of Way on line of road. 1892-93, Assistant Engineer Long Island R. R., and Engineer for Ferris & Richards, Contractors for Railroads and Waterworks, at 98 Hudson street, Jersey City, N. J. 1893–94, with James R. Croes, C. E., Waterworks Supply and Sewerage, 1894. Private practice as Small & Schumann, Architects and Civil Engineers.

SEARLE, CHARLES D., C. E., ... 1896.
32 West 126th Street, New York City.

SELIGMAN, JOSEPH GUY, E. M., ... 1887.
Mining Superintendent, and 506 W. 143d Street, New York City.

SELDNER, RUDOLPH, PH. B., ... 1894.
Adelphi College and 217 Jefferson Avenue, Brooklyn, N. Y.

Instructor in Science Adelphi Academy, 1894 to date.

SELF, E. D., E. M., ... 1894.
Box 550, Johannesburg, South Africa and South Orange, N. J.

Received degree of Mechanical Engineer at the Stevens Institute of Technology in 1886. Engaged in engineering and construction work. Designing and pur-

chasing machinery for large mills in Australia and Mexico. Report on transmission of power project for mining plant in Mexico. Examination of mines in South America. Superintendent of mine in Guyana, South America. Received degree of Engineer of Mines from Columbia College in 1894. Instructor in Mining at Lake Superior for class in practical mining. Supt. and Manager of the Sonora Copper Co., Sonora, Mexico. Received patent for system of ore concentration. Consulting Mechanical and Mining Engineer on deep level work, to an English Investment Co., and to several mining companies.

SEWARD, JOHN, E. M., ... 1895.
97 Cedar St., New York City, and 416 Main Street, Orange, N. J.

SHARE, WILLIAM WALDEMAR, PH. B., PH. D., . . 1881.
Adelphi College, and 331 McDonough Street, Brooklyn, N. Y.

1881, Superintendent Columbia Chemical Works, Brooklyn, N. Y. 1881–88, Assistant Physics, Columbia College. 1888, Consulting Electrician, Department of Public Parks, Brooklyn, N. Y. 1889 to date, Professor of Chemistry, Adelphi Academy, Brooklyn, N. Y.

SHATTUCK, L. R., B. S., C. E. . . . . 1895.
138 Eighth Avenue, Brooklyn, N. Y.

1895, Draughting and Field work with the Ramapo Water Co. 1896, Engineer Inspector in the Dept. of Public Works, of New York City.

SHERMAN, FRANK DEMPSTER, PH. B., ... 1884.
Adjunct Professor of Architecture, School of Mines, Columbia University, New York City, 312 South Broadway, Yonkers, N. Y.

SHRIVER, HENRY TOWER, PH. B., ... 1888.
T. Shriver & Co., 333 E. Fifty-sixth Street, and 686 Park Avenue, New York City.

In Iron Foundry and Works, as above, since graduation.

SIMONDS, FRANCIS MAY, E. M., PH. D., . . . 1887.
147 E. Thirty-fourth Street, New York City.

SINGER, GEORGE, JR., E. M., ... 1880.
111 Fourth Avenue, Pittsburg, Pa.

SINGER, GEORGE HARTON, E. M., ... 1880.
Singer, Nimick & Co., and 17 Park Street, Allegheny, Pa.

SKINNER, ELMER, C. E., ... 1891.
227 Cumberland Street, Brooklyn, N. Y.

SLACK, CHARLES GODDAR, E. M., ... 1884.
328 Fourth Street, Marietta, Ohio.

SLADE, RICHMOND EDWARD, PH. B., ... 1887.
White Plains, N. Y.

1887, Assistant Superintendent United Gas Improvement Co., Yonkers, N. Y., Plants. 1888, Superintendent Gas Department, Ashville (N. C.) Light and Power Co. 1888, Superintendent Gas and Electric Plants, Citizens' Gas Light

Co., Jackson, Tenn. December, 1889, to date, Secretary, Superintendent and Trustee Citizens' Gas and Electric Co., White Plains, N. Y. 1896, Secretary and Superintendent and Trustee Citizens' Gas and Electric Co., Secretary and Director N. Y. Elmsford and White Plains Ry. Co., and Manager Consolidated Gas and Electric Light Co., of Westchester County, Port Chester, N. Y.

SMITH, AUGUSTUS, A. B., C. E., ... 1889.
39 Cortland St., and 460 W. Forty-fourth St., New York City.

Summer of 1886, Land Surveying (in charge of Party). July to November, 1889. Draughtsman, Link Belt Engineering Co., Nicetown, Phila. November, 1889–91, Chief Draughtsman, New York Office Link Belt Engineering Co. 1891–92, out of professional work. 1882, Salesman and Engineer as above. 1893 to date, private practice as Engineer and Contractor.

SMITH, FRANK MARSHALL, E. M., ... 1889.
Supt. United Smelting and Refining Co., Smelter, Cascade Co., Mont.

1889–90, on the United States Geological Survey, engaged in hydrographic work on the Irrigation Survey and triangulation of the Topographic Survey, in Idaho and Oregon. 1891, Assayer Colorado Smelting Co., Pueblo, Colo. October, 1892–93, Assistant Superintendent. 1893 to date, Supt. United Smelting and Refining Co., Smelter, Mont.

SMITH, FRANCIS PITT, PH. B., ... 1888.
77 Woodlawn Avenue, New Rochelle, N. Y.

Analytical Chemist in Leather trade, 1888–89. Superintendent Chemical Works, Wm. H. Swift & Co., East Boston, Mass., 1889–90. Consulting Chemist, Dening & Logan, 58 William Street, 1890. Assistant Chemist New York City Health Department, 42 Bleecker Street, 1890–92. Specialty, Chemical Mechanics. 1892–93, Inspection Brooklyn Navy Yard. 1896 with Harrison Bros. & Co., Phila., Pa.

SMITH, LENOX, A. B., A. M., E. M. (Life Member), . 1868.
120 Broadway, New York City.

SMITH, WILSON FITCH, C. E., ... 1894.
36 West 36th Street, New York City.

June to Oct., 1894, Assistant Instructor Summer School of Surveying, School of Mines, Columbia University. Oct., 1894–96, Engineering Department, New York Central & Hudson River R. R., as Rodman and Assistant Engineer at present with R. W. Hildreth & Co., Civil Engineers.

SMITH, WILLIAM ALLEN, E. M., ... 1868.
52 Wall Street, and 102 East Fifty-seventh Street, New York City.

SMYTH, CHARLES HENRY, JR., PH. B., PH. D., . . 1888.
Professor of Geology, Hamilton College, Clinton, New York.

1888–89, Chemist Franklin Iron Mfg. Co. 1889–90, Geological Field Work in New York, Alabama, Georgia, and Tennessee. June, 1890, received Degree of Doctor of Philosophy from Columbia University. 1889–91, studied Petrography and Mineralogy with Prof. Rosenbusch at the University of Heidelberg. 1891,

appointed Professor of Geology in Hamilton College. Engaged in the study of the Western Adirondack region, and the investigations of problems in central New York. Chiefly in Petrographic, Chemical and Glacial Geology. Asst. on N. Y. Geol. Survey, 1893–95. Professor of Geology and Mineralogy. Interested chiefly in Petrographic and Chemical Geology, and in Mineralogy.

SNOOK, THOMAS EDWARD, E. M., ... 1884.
Architect, 261 Broadway, New York City.

1884–87, Supt. Cons. for John B. Snook, Architect. 1887 to date, Member of the firm of and Chief Engineer for John B. Snook & Son, Architects.

SOUTHARD, GEORGE CARROLL, C. E., ... 1892.
66 Beaver Street, New York City, and 111 Montague Street, Brooklyn, N. Y.

June, 1892, to March, 1893, Equity Gas-Works Construction Co., Brooklyn, E. D. March, 1893, to January, 1894, with Heine Safety Boiler Co. January, 1894–95, with Hecker-Jones-Jewell Milling Co. From Aug., 1895, to date, with Southern Pine Co., of Ga.

SPOONER, ALLET NAWHALL, C. E., ... 1886.
Department of Docks, Pier A, North River, New York City, and 186 Carteret Avenue, Jersey City, N. J.

July, 1886, to August, 1887, Rodman and Draughtsman, Penn. R. R., Jersey City. August, 1887, to May, 1890, Hydrographer Department Docks, New York City. May, 1890-91, to present time, Assistant Engineer Department Docks, New York City. Specialty, Railroad Engineering, River, Submarine and Harbor Engineering.

STANTON, FRANK MCMILLAN, E. M., ... 1887.
Superintendent Atlantic Mine, Houghton Co., Mich.

1887–88, Superintendent *pro tem.* Central Mine, Mich. 1888-89, Engineer Atlantic Mine, Mich. 1889 to date, Superintendent Atlantic Mine, Mich.

STAREK, EMIL, LL. B., LL. M., E. M., ... 1895.
Keller & Starek, Patents, 703 Commercial Building, and 4204 A, Cook Avenue, St. Louis, Mo.

1885–87, Assistant in United States Geological Survey. 1887-92, Assistant Examiner United States Patent Office, Washington, D. C.

STARR, CHANDLER DANNAT, C. E., ... 1881.
Andress unknown.

STAUNTON, WILLIAM FIELD, E. M., ... 1882.
Superintendent of the Congress Gold Co., Congress, Ariz.

1882, Assayer and Assistant Superintendent Vermont Copper Co., Ely, Vt. 1882, Assayer and Accountant Dunn Mt. Gold Mine, Salisbury, N. C. 1883, Assayer Ledoux & Ricketts, N. Y. 1883, Constructing Engineer, C. M. and R. Co., N. Y. 1883, Assistant to Manager of Mills and Smelting of T. M. and M. Co., Tombstone, Arizona. 1884, Consulting Engineer, N. Y. 1884, Mining Engineer for T. M. & M. Co., Tombstone, Arizona. 1890 to date, Superintendent Tomb-

stone Mill and Mining Co., Tombstone, Ariz., and 1894, Superintendent Congress Gold Co., Congress, Ariz. Specialty, Gold and Silver Mining and Metallurgy.

STEARNS, THOMAS BEALE, E. M., ... 1881.
1720 California Street, Denver, Colo.

STEWART, JOHN HENRY, C. E., ... 1895.
Dept. of Public Works, 150 Nassau Street, and 123 West Eleventh Street, New York City.

STONE, GEORGE CAMERON, PH. B., PH. D., . . . 1879.
New Jersey Zinc and Iron Company, Newark, N. J.

1879, Chemist, Booth & Edgar Sugar Refinery. 1879–82, Chemist with Potter & Riggs, St. Louis, Mo. 1882–91, with New Jersey Zinc and Iron Company, Newark, N. J., first as Chemist; since 1884, as Superintendent Blast-Furnaces. May, 1894, to date, Superintendent of company.

STRUTHERS, JOSEPH, PH. B., PH. D., ... 1885.
Tutor in Metallurgy, Columbia College School of Mines, and 624 East One Hundred and Thirty-sixth Street, New York City.

1885–88, Fellow in Mineralogy. 1888–90, Assistant in Mineralogy and Metallurgy. 1891 to date, Tutor in Metallurgy Columbia University, School of Mines. 1893–94, Delivered the lectures in Metallurgy at the School of Mines, in place of Dr. Egleston, who was absent on account of sickness. Summer of 1894 spent in Europe in the study of metallurgical works and processes. 1894–95, Special work upon pyrometers and calorimeters. Spring, 1896, Delivered the lectures in Metallurgy at the School of Mines, in place of Dr. Egleston. Summer of 1896, in charge of the Summer School in Practical Metallurgy at Butte, Mont., and devoted three months to a metallurgical trip throughout the western United States and British Columbia, visiting more than forty establishments. Jan. 1, 1897, in charge of the lectures in Metallurgy at the School of Mines, in the absence of Dr. Egleston, resigned. Specialty, the measurements of high temperatures and the physical properties of slags.

STUART, WILLIAM HENRY, C. E., ... 1886.
Address unknown.

1886, on Railway Surveys in Minnesota and Wisconsin with C. B. & N. R. R. Co. 1887–89, Fellow in Engineering and Assistant in Summer School of Surveying, School of Mines, Columbia University. 1889–90, making surveys and superintending construction at the Hudson River State Hospital, Poughkeepsie, N. J. 1890, on surveys in the West Indies. 1893, in general practice.

SUTER, GEORGE AUGUSTUS, E. M., ... 1883.
G. A. Suter & Co., Engineers and Contractors, 112–114 Wooster Street, New York City, and 78 Locust Ave., New Rochelle, N. Y.

1884–92, Engineer, Baker, Smith & Co. 1892–97, with G. A. Suter & Co.

SWAIN, ALFRED ERNEST, E. M., ... 1881.
Supt. Trinidad Mining Co., Copala (via Mazatlan, Sinaloa, Mexico), and 902 Prospect Street, Cleveland, O.

1881–84, railroad work in Mexico. 1885–88, City Engineer's Department, Kansas City, Mo., in charge of sewer work. 1889–91, mining work in Mexico. 1891, Supt. San Buenaventura Mining Company, Santa Lucia, Sinaloa, Mexico, via Mazatlan and Pana. 1891–93, Supt. Trinidad Mining Co.

T.

TAINTOR, WILLIAM NOYES, PH. B., ... 1894.

Care Division Engineer N. Y. State Canals, Syracuse, and 60 West Forty-eighth Street, New York City.

August, 1894, to September, 1894, Levelman, Metropolitan Traction Co. September, 1894, to date, Transitman, Ramapo Water Co.

TAYLOR, JOSEPH B., E. M., ... 1888.

56 and 58 Pine Street, New York City, and 404 Seneca Street, Brooklyn, N. Y.

June–Sept., 1894, Rodman, Lexington Ave. Cable Road. Sept., 1894, to Feb., 1895, Topographic Surveys, Ramapo Water Company. Feb.–May, 1895, City Surveying, New York. July–Oct., 1895, Assistant, Summer School in Surveying, Columbia University. March, 1896, to date, Leveler, N. Y. State Canals.

TEMPLE, SETH JUSTICE, PH. B., ... 1892.

Address unknown.

Instructor in Architectural Drawing Art Schools of the Metropolitan Museum of Art, Fifth Ave. and Thirty-Second Street, New York City.

TERHUNE, RICHARD HENRY, E. M., ... 1870.

64 Sixth South Street, Salt Lake City, Utah.

1870, Assistant to late J. W. Foster, geology of coal fields, Indiana. 1871, Griswold Steel Works, draughting, blowing steel, etc. 1872–77, Joliet Steel Company, draughting, inspecting steel rails and exploration of Callaway County, Missouri, for coal and iron. 1877–80, Superintendent and Assistant Superintendent Smelting Works in Utah. 1880–93, General Superintendent Hanauer Smelting Works, Utah. Specialty, construction and operation of lead smelting works. Resigned above position September, 1893. 1894, Examining and Reporting on Mines and Works. October, 1896, reëlected to the position of Chief Engineer and General Superintendent of the Hanauer Smelting Works, Utah.

THACHER, ARTHUR, C. E., E. M., ... 1877.

President and General Manager Central Lead Company, 4109 Washington Avenue, St. Louis, Mo.

1878–79, with Progreso Mining Company, Trimfo, Lower California, Mexico. 1879–83, Southern Arizona and Northern Mexico Mining and Milling. 1883–87, office in New York. Examining and reporting on mines and mills. 1887 to date, with Professor W. B. Potter, at St. Louis Sampling and Testing Works and Washington University. Lecturing on Metallurgy. Testing ores, etc. Examining and reporting on mines and mills. Superintendent Central Lead Co.

THOMAS, FREDERICK MAYHEW, E. M., ... 1885.

1331 Vine Street, Denver, Colo.

Leveller (Instrument man, etc.), on New York State Canals, from September, 1887, to November, 1889 (position resigned). Transitman and leveller on preliminary railroad survey in Schoharie County in spring of 1890. Transitman and leveller on Syracuse Water Works during the winter of 1890–91.

THOMPSON, HENRY CLARK, C. E., ... 1886.
Lorillard Place, and One Hundred and Eighty-Seventh and One Hundred and Eighty-eighth Streets, New York City.

TIBBALS, GEORGE ATWATER, C. E., ... 1883.
Continental Iron Works, and 148 Milton Street, Brooklyn, N. Y.
1883 to date, as above.

TIBBALS, SAMUEL GAYLORD, C. E., ... 1884.
Continental Iron Works, and 148 Milton Street, Brooklyn, N. Y.
1884 to date, as above.

TILDEN, GEORGE CYRUS, C. E., ... 1876.
Address unknown.
1876–80, City Surveyor, Brooklyn, N. Y. 1880–81, Superintendent Dunderberg Mining Company, Georgetown, Colo. 1881–82, Chemist and Assayer, Denver, Colo. 1882 to date, Professor Analytical Chemistry State School of Mines, Golden, Colo. 1881 to date, Consulting Practice as Mining Engineer. Specialty Analytical Chemistry and Assaying.

TITUS, WARREN HARRIOTT, E. M., ... 1885.
Sanitary Engineer, Lincoln Building, 1 Union Square, New York City, N. Y., 220 Fourth Avenue and 80 E. Washington Square, New York City, and Whitestone, N. Y.
1885–86, Post Graduate Course in Civil Engineering School of Mines and traveling in Europe. From 1886–92 in the Board of Health employed as follows: From Oct., 1886–87, Assistant Sanitary Engineer and Inspector of Plumbing. From 1887–88, Assistant Sanitary Engineer and Special Inspector of Plumbing, Drainage, Light and Ventilation. From 1888, to Nov., 1890, Assistant Sanitary Engineer and Special Inspector and Examiner of Plans for Plumbing, Drainage, Light and Ventilation. From Nov., 1890, to June, 1892, Assistant Chief Inspector of the Division of Plumbing, Drainage, Light and Ventilation. From Dec., 1891, to June, 1892, Acting Chief Inspector in charge of Division of Plumbing, Drainage, Light and Ventilation. From June, 1892, to Oct., 1895, Examiner of Plans for Plumbing, Drainage, Light and Ventilation in the Department of Buildings of New York City. 1895, Practicing as Sanitary Engineer, New York City.

TOMPKINS, E. DE V., C. E., ... 1896.
Union Bridge Company, Athens, Pa., and 632 West End Avenue, New York City, N. Y.
Assistant Instructor Summer School of Surveying, Summer of 1895. One week after graduation to present time, with Union Bridge Co., Athens, Pa.

TONNELÉ, THEODORE, PH. B., ... 1880.
Care of Wm. Dewees Wood Co., McKeesport, Allegheny Co., Pa.

In charge of Refining and Steel Departments of the William Dewees Wood Company.

TOWER, ALBERT EDWARD, E. M., ... 1883.
Poughkeepsie Iron Company, Poughkeepsie, N. Y.

TOWER, FREDERIC WETHERWAX, E. M., . . . 1887.
Assistant Examiner, Room 223 Patent Office, and 1400 L Street, N. W., Washington, D. C.
1888 to date, as above.

TOWNSEND, S. G. F., E. E., ... 1896.
Ward Leonard Electric Company, Hoboken, N. J., and 131 5th Avenue, New York City.

TRAPHAGEN, FRANK WEISS, PH. B., PH. D., . . . 1882.
Chemist in charge of Chemical Laboratory, Montana College of Agriculture, Bozeman, Mont.
1883–84, Chemist for Williams, Clark & Co., Fertilizers. 1884–87, Instructor in Chemistry and Physics, Staunton Military Academy, Staunton, Va. 1887, Professor of General, Analytical and Applied Chemistry and Assaying in the College of Montana and Montana School of Mines. 1884–87, Analytical and Consulting Chemist, Staunton, Va. 1887, Principal work, fertilizer, iron and steel, clays, etc. Analytical and consulting Chemist and Assayer, Deer Lodge, Mont. Assaying, miscellaneous analysis and legal work. 1890, Assayer for the Champion Consolidated Mining Company, Deer Lodge, Mont. 1892–93, in charge Montana Mining Exhibit at Columbian Exhibition. 1893, Professor Chemistry, Montana College of Agriculture and Mech. Arts. 1895, Chemist Montana Agricultural Experiment Station.

TRASK, GEORGE FRANCIS DONNELL, E. M., . . . 1887.
Member of firm of Trask, Burns & Co., Electric Railway Contractors, 99 Cedar Street, New York City.
1888–90, Apprentice and Machinist, L. & N. Railroad. 1890–91, Draughtsman, L. & N. Railroad, Louisville. In 1895–96, doing business as George F. D. Trask, Electric Railway Contractor; in 1896, as member of Trask, Burns & Co., Electric Railway Contractors.

TUSKA, GUSTAVE ROBITSCHER, B. S., M. S., C. E., . 1891.
29 Broadway and 55 East Sixty-fifth Street, New York City.
1891–92, Civil and Mechanical Engineer Link-Belt Engineering Co., Philadelphia. 1892–93, Bridge Engineer, Long Island Railroad. Assistant Engineer C. N. Y. and W. R. R., in charge of Stony Brook viaduct, 1893. Consulting Engineer Port-au-Prince Ry., Cuba, 1893 to date. Resident Engineer, Knoxville, Cumberland Gap and Louisville R. R. Co., in charge of Construction of Louisville Viaduct, 1893. Assistant to Professor of Civil Engineering, Columbia College, 1893. Tutor in Civil Engineering, School of Mines, 1894–95. 1896, Chief Engineer Panama Railroad Co., and in general practice as Consulting Engineer.

TUTTLE, EDGAR GRANGER, E. M., ... 1881.
227 Pearl Street, New York City.

1881, Assistant Engineer, Tilly Foster Iron Mine, Brewster, N. Y. 1881–82, Division Engineer, Wheeling & Lake Erie R. R., Toledo, O. 1882–83, Assayer and Mining Engineer, Silver City, New Mexico. 1883–85, Division and Office Engineer, Arizona & New Mexico Railroad, Lordsburg, Arizona. 1885, Constructing Engineer at Mines, Arizona Copper Co., Clifton, Arizona. 1885–89, Mining Engineer, Cambria Iron Co., Johnstown, Pa. 1889–94, Superintendent Alamo Coal Co., and Coahuila Coal Co., San Felipe, Coahuila, Mexico. Box 109, Eagle Pass, Texas. 1894, Examinations in Deep River Coal Field for Egypt Coal Co., North Carolina. 1894, Examination in Pocohontas Field, West Virginia, 1895, Writing "Surface Arrangements of Bituminous Mines," for Correspondence School of Mines, Scranton, Penna. 1895, Expert Examinations of Property and Operations of Columbus & Hocking Coal and Iron Co., Columbus, Ohio, for Bondholders' Committee.

TYLER, WALTER LINCOLN, C. E., ... 1887.
116–120 Front Street, and 1314 Pacific Street, Brooklyn, N. Y.

1887, Levelman and Transitman on the Roanoke & Southern Railroad, Va. 1888, with J. A. Lathan, C. E., Providence, R. I. 1888–89, with F. N. Owen, E. M., Sanitary Engineer, New York City. 1889 to the present time, with the A. B. See Manufacturing Co., 116–120 Front Street, Brooklyn.

V.

VAIL, LEWIS H., E. E., ... 1894.
Locust Valley, Long Island, N. Y.

VALUE, BEVERLY REID, E. M., ... 1884.
Address unknown.

VANDERBILT, WILLIAM D., C. E., ... 1894.
39 Monroe Place, Brooklyn, N. Y.
Leveller, Department of City Works, Brooklyn, N. Y.

VANDERPOEL, FRANK, E. M., ... 1875.
Chemist, The Celluloid Co., 295 Ferry Street, and 191 Roseville Avenue, Newark, N. J.
1875–78, Salesman, with E. B. Benjamin. 1878 to date, as above.

VAN ARSDALE, WILLIAM HENRY, A. B., A. M., E. M., . 1868.
Vice-President Chicago and Aurora Smelting and Refining Co., Chicago, Ill.

VAN BLARCOM, ELBERT CHAMPLIN, C. E., . . . 1876.
Care H. de San Francisco Pachuca, Hidalgo, Mexico.

VAN CORTLANDT, EDWARD NEWENHAM, E. M., . . 1885.
508 Cooper Building, Denver, Colo., and Tuxedo Park, N. Y.

VAN DYCK, EDWIN, PH. B., ... 1888.
1080 Dean Street, Brooklyn, N. Y.

VAN SINDEREN, ALVAN HOWARD, PH. B., . . . 1881.
Attorney and Counselor-at-Law, 15 Broad Street and 14 West 16th Street, New York City.

VAN VOLKENBURGH, EDWARD, JR., C. E., . . . 1888.
Morgan & Bartlet, 41 Wall Street, New York City.

VAN WAGENEN, THEODORE FRANCIS, E. M., . . . 1870.
Box 589, Telluride, Colo., and 809 16th Avenue, Denver, Colo.
1893, President and General Manager of the Deming Ore Co., Deming, Grant Co., New Mexico. 1894, Consulting Mining Engineer, Denver, Colo. 1896, Muge Flora-Chmax Gold Mines, Telluride, Colo. 1897, Cons. Eng. Southwestern Copper Mining Co. (Ltd.).

VOLCKENING, GUSTAV JULIUS, MET. ENG., E. M., . . 1888.
Department of Health and 65 Van Buren Street, Brooklyn, N. Y.

VONDY, RUDOLPH HARRISON, E. M., ... 1882.
305 Montgomery Street, Jersey City, N. J.
1882-83, Assistant Engineer, Tilly Foster Iron Mine. 1885-92, Chemist Phœnix Iron Works, Phœnixville, Pa. 1892, Supt. Plenty Hort'l and Skylight Works.

VON NARDROFF, ERNEST ROBERT, E. M., . . . 1886.
Instructor of Physics, Barnard College, 343 Madison Avenue, New York City, and 360a Tompkins Avenue, Brooklyn, N. Y.

VULTÉ, HERMANN T., PH. B., PH. D., ... 1881.
Assistant in Quantitative Analysis, School of Mines, New York City, and New Rochelle, N. Y.
1881-82, Superintendent Columbia Chemical Works, Brooklyn, N. Y. 1883-91, Assistant Instructor in Analytical Chemistry, School of Mines. Engaged in investigating new Analytical Methods. Specialty: Commercial Organic Analysis Expert in Oils, Fats, Soap, etc.

W.

WAINWRIGHT, JOHN HOWARD, PH. B., ... 1882.
Chemist, 402 Washington Street, New York City.

WALKER, H. V., PH. B., ... 1894.
38-40 Clinton Street, Brooklyn, N. Y.

WALKER, ARTHUR LUCIEN, E. M., ... 1883.
General Manager Baltimore Electric Refining Company, Keyser Building, Baltimore, Md.
1883-84, Chemist and Assayer, Old Dominion Copper Co., Globe, Arizona. 1885, Assistant Superintendent of same company. 1886, engaged in connection with Iron Metallurgy in New York City. 1887, Mechanical Engineer for Silver King Mining Co., Silver King, Arizona. 1888-93, Superintendent, Old Dominion Copper Co., Globe, Arizona. Also report on all classes of Mining and Metallurg-

ical Property in Arizona. 1893-95, Consulting Engineer Old Dominion Copper Co. 1893 to date, General Manager Baltimore Electric Refining Co., Baltimore, Md.

WALLER, ELWYN, A. B., A. M., E. M., PH. D., . . 1870.
7 Franklin Place, Morristown, N. J.

1871, Assistant Analytical Chemistry, School of Mines. 1877, Instructor Analytical Chemistry, School of Mines. 1885-93, Professor Analytical Chemistry, School of Mines. 1872-85, Inspector and Chemist N. Y. Health Department.

WAMPOLD, LEO, PH. B., ... 1888.
204 Monroe Street, Chicago, Ill.

WARD, DELANCY WALTON, PH. B., ... 1888.
Whitestone, N. Y.

WARNER, JOSEPH LOWERY, E. M., ... 1887.
P. O. Box 621, Spokane, Wash.

August, 1887, to August, 1888, Omaha and Great Smelter, Denver, Assistant Assayer. August, 1888, to July, 1889, Examination of and Reports on Mines in Cœur d'Almes, Idaho and in O'Kanagrn Mining District, Washington. Manager La Bellevue Mine, same district. July, 1889, to January, 1890, Assistant Superintendent and Amalgamator, Golden Monarch Mine, Oregon. January, 1890-92, Examination and Reports on Mines in Western Washington. Manager, Culver Mining Co. and V. P. Vermilion Iron Co. 1892, Examinations in Cascade Range. 1893, Examinations of Iron Deposits, Island of Texado, British Columbia.

WATSON, FREDERICK MORGAN, E. M., ... 1885.
Consolidated Gold Fields of South Africa, Buluwayo, Rhodesia, South Africa, and 403 Sibley Street, Cleveland, Ohio.

1885, Assayer and Surveyor, La Maria Mining Co., Mexico. 1886-89, Engineer, Mill Superintendent, Sombrerete Mining Co., Mexico. Concentration and Lixiviation. 1890, Engineer for Peru Exploration Syndicate, Ltd., Peru. 1891 to date, Examining Engineer for Frecheville Bros. Special Experience in Roasting Rebellious Ores. Lixiviation by Russell Process and Superintendent as above. Superintendent "Cia Andes" till 1895. 1896, Engineer Consolidated Gold Fields of South Africa.

WATSON, ROLLA BARNUM, E. M., ... 1891.
Care Daly Mining Co., Park City, Utah, and 551 Sibley Street, Cleveland, Ohio.

Assayer, Candemena, Mexico, 1891. Supt. Erection of Power Plant for Electric Street R. R., Atlanta, Ga., 1892. September, 1893, with Dewey-Walter Refining Co., Marsac Mill, Park City, Utah. December, 1893, to date, Superintendent Dewey-Walter Refining Co. Also from May, 1895, Foreman Marsac Leacher. 1896, Assistant Manager Russell Process Co. and with Daly Mining Co., Park City, Utah.

WEDEKIND, EDWIN HUTRER, PH. B., ... 1889.
Northport, British Columbia.

WEED, WALTER HARVEY, E. M., ... 1883.

U. S. Geological Survey, Washington, D. C., and care S. R. Weed, South Norwalk, Conn.

1883 to date, Geologist on the United States Geological Survey. 1883–89, general geology of the Yellowstone National Park, especially of sedimentary rocks, with examinations of the adjacent mining regions. 1890, structural and economic geology of the country north of the Yellowstone Park, with special studies of the coal-fields of Montana. Specialty, economic and stratigraphic geology. Publications: "A deadly Gas-spring in the Yellowstone National Park."—*Science.* "The Diatom-beds and Marshes of the Yellowstone National Park."—*Botanical Gazette.* "The Formation of Hot Spring Deposits." Ninth Annual Report of the Director U. S. Geological Survey. "Geysers."—SCHOOL OF MINES QUARTERLY. "Notes on the Coal-fields of Montana."—SCHOOL OF MINES QUARTERLY. "The Cinnaba and Bozeman Coal-fields of Montana."—*Bulletin Geological Society of America,* and other papers.

WEEKS, WILLIAM HOLDEN, PH. B., ... 1889.

789 Madison Avenue, New York City.

1889–90, Assistant Chemist, New York Chemical Manufacturing Company. April, 1890, to date, Assistant Chemist Health Department, New York City.

WELCH, ALEXANDER MCMILLAN, PH. B. (Arch.), . . 1890.

447 Lexington Avenue and 503 Fifth Avenue, New York City.

1890–91, in architect's office. 1891–93, McKim Fellow, traveling in Europe. 1893 to date, as above.

WELLS, JAMES SIMPSON CHESTER, PH. B., PH. D., . 1875.

Columbia University, School of Mines, New York City, and 221 Union Street, Hackensack, N. J.

1875–79, Assistant in Quantitative Analysis, School of Mines. Vacation of 1877, spent as Night Superintendent Pennsylvania Lead Works. 1879-93, Instructor in Qualitative Analytical Chemistry, School of Mines.

WERTHEIMER, LEWIS, PH. B., ... 1887.

Western and Bedwell Streets, Allegheny City, Pa.

WESTERVELT, WILLIAM Y., E. M., ... 1894.

Acting Mining Superintendent Ducktown Sulphur, Copper and Iron Co., Isabella, Polk County, Tenn.

1894–95, Chemist and Surveyor, Ducktown Sulphur, Copper and Iron Co., Ltd. 1895-96, Engineer and Chemist, same company. 1896, Acting Mining Superintendent, same company.

WHEELER, HERBERT ALLEN, E. M., ... 1880.

1416 Chemical Building, and 3124 Locust Street, St. Louis, Mo.

During 1880, Assistant Geologist in Utah, on U. S. Geological Survey. During 1881, Assistant Engineer Denver and Rio Grande Western Railroad, in Utah and Colorado, on location and construction. During 1882, Superintendent Vermont Copper Company, Ely, Vermont. From 1883 to 1894, at Washington University, St. Louis; Adjunct Professor of Mining; also Consulting Mining Engineer.

Since 1891, Assistant Missouri Geological Survey. 1894, Consulting Mining Engineer. 1896, Secretary and Treasurer, Standard Tile Co.

WHITE, ROBERT DAVIS, C. E., ... 1892.
39 East Seventy-fourth Street, New York City.

WHITE, THEODORE G., PH. B., M. A., ... 1894.
Geol. Department, Columbia University, and 39 West Twenty-sixth Street, New York City.

Summer of 1893, working on the Geology of the Lake Champlain region. Summer of 1894, traveling and examining mining regions surrounding the Great Lakes in Canada and United States, also researches on the Geology of Mt. Desert Island, Maine. 1894 and 1895, Post-Graduate Student in Geology. Researches on the Trenton formation of the Lake Champlain Valley. 1895-96, Lecturer, N. Y. Board of Education. 1896, Assistant in Physics, Columbia University.

WHITING, LOWE, E. M., ... 1895.
Care Messrs. Gaminara & Selder, Tumaeo, Rep. Colombia, S. A.

WHITLOCK, HERBERT PERCY, C. E., ... 1889.
Assistant in Mineralogy, Columbia University, School of Mines, and 449 Park Avenue, New York City.

WIECHMANN, FERDINAND G., PH. B., PH. D. . . 1881.
Instructor in Chemical Philosophy and Chemical Physics, Columbia University, School of Mines, and 671 West End Avenue, New York City.

Consulting Chemist American Sugar Refining Co., Brooklyn, N. Y.

WIENER, WILLIAM, A. M., PH. B., ... 1891.
Newark High School, and 62½ Nelson Place, Newark, N. J.

1891-92, Chemist to the Hanson, Van Winkle Co., Newark, N. J. 1892-93, Chemicals for Electro-plating, 87 and 89 Mechanic Street, Newark, N. J. 1893 to date, Instructor in Newark High School, and general chemical practice.

WILLIAMS, GRANVILLE WHITTLESEY, E. M., C. E., . 1879.
323 Genesee Street, Utica, N. Y.

WILLIAMS, JOHN TOWNSEND, E. M., PH. B., . . . 1873.
Architect and Builder, 906-914 New York Life Building, 346-348 Broadway, New York City, and Stamford, Conn.

WILLIAMS, WILLIAM FISH, C. E., E. M., . . . 1881.
City Engineer, 224 Pleasant Street, New Bedford, Mass.

Chief Engineer, later also Assistant Manager to Cumberland Lands, Ltd., of Stewart County, Tenn. 1890-93, City Engineer New Bedford, Mass. 1893 to present time, also Chief Engineer at present on the construction of the New Bedford and Fairhaven Bridge.

WILLIS, BAILEY, E. M., C. E., ... 1878.
U. S. Geological Survey and 2117 Bancroft Place, Washington, D. C.

June, 1879, to July, 1881, Special Agent Tenth Census; sampler of iron ores and student of iron deposits in states east of the Mississippi river. August, 1881, to June, 1884, Geologist in charge of Pacific division of Northern Transcontinental Survey, chiefly engaged in coal explorations in Washington, Oregon and Montana. July, 1884, to February, 1889, Assistant Geologist U. S. Geological Survey, working in Tennessee and North Carolina. March, 1889, to June, 1893, Geologist in charge of Appalachian division, U. S. Geological Survey, directing work and studying geologic problems of the Palæozoic rocks south of Pennsylvania. 1891–93, Editor of Geologic Maps for Folios of the Geologic Atlas of the United States. In 1895–96, Geologist in charge of operations in the Cascade Range and Puget Sound Basin, Washington.

WILSON, HERBERT M., C. E., ... 1881.
U. S. Geological Survey, Washington, D. C.

1881–82, Leveller and Transitman, afterwards Chief of Preliminary party, S. & D. R. R., Mexico. 1882–88, Topographer U. S. Geological Survey. 1889–90, Division Engineer, U. S. Irrigation Surveys. 1891, Geographer, U. S. Geological Survey. 1894, Chief Geographer.

WILSON, WILLIAM ALEXANDER, E. M. . . . 1882.
Chamber of Commerce, Salt Lake City, Utah.

Assayer for two and a half years. Superintendent of Sampling Mill for two years. Superintendent of 30-Stamp Mill (dry crushing, chloridizing, amalgamating and lixiviating, capacity sixty tons per day) for five years. Specialty, treatment of silver and gold ores and examining and reporting on mining properties. Superintending of Mining or Milling operations. U. S. Deputy Mineral Surveyor.

WILTSIE, ERNEST ABRAM, E. M., ... 1885.
General Manager Geldenhuis Estate and Gold Mining Co., Johannesburg, South African Republic.

1885–86, Assistant Chemist Edgar Thomson Steel Works, Braddock, Pa. 1886 to May, 1887, Chemist Colorado Coal and Iron Company, Pueblo, Colo. May, 1887, to August, 1888, Chemist for the Globe Smelting and Refining Company, Denver, Colo. August, 1888, to April, 1890, Assistant Superintendent North Star Mining Company, Grass Valley, Cal. April, 1890–91, Superintendent Menlo Mines, Grass Valley, Cal. January, 1892, Expert work, Nevada Co., Cal. January to August, 1892, with California State Mining Bureau. August, 1892, to January, 1893, Expert work through California. April, 1893, Manager Gold Mines for Barnato Bros., Johannesburg, So. Africa. July 1, 1894, Geldenhuis Est. and Gold Mining Co., Johannesburg, S. A. Rep.

WINDOLPH, AUGUSTUS PAUL, PH. B., ... 1892.
Address unknown.

WITTMACK, CHARLES AUGUSTUS, M. S., PH. B., PH. D., . 1882.
675 Hudson Street, New York City.

WOOLSON, IRA HARVEY, E. M., ... 1885.
Columbia University School of Mines, New York City.

1885–86, Assistant Geological Survey of New Jersey. 1886–87, Assistant Assay Department, School of Mines. 1887–89, Assistant, Drawing Department School of Mines. 1891 to date, Instructor Mechanical Engineering and Drawing, School of Mines, Columbia University.

Y.

YEIZAR, ROBERTO, E. M., ... 1895.
A. P. 27, Zacatecas, Mexico, also care C. Viaders, 14–16 South William Street, New York City.

YOUNG, EDWARD LEAVITT, E. M., ... 1882.
American buyer Takata & Co., of Tokio, Japan, 10 Wall Street and 317 West Eighty-ninth Street, New York City.

HONORARY MEMBERS.

CHANDLER, CHARLES F., PH. D.

Professor of Chemistry, School of Mines, Columbia University. Address, 51 East Fifty-fourth Street, New York City.

EGLESTON, THOMAS, E. M., PH. D.

Professor of Mineralogy and Metallurgy, School of Mines, Columbia University. Address, 35 West Washington Square, New York City.

MILLER, GEORGE M.

Ringwood, New Jersey.

ROOD, O. N., A. M.

Professor of Physics, Columbia University. Address, Columbia University, New York City.

VAN AMRINGE, J. H., A. M., PH. D.

Professor of Mathematics, School of Mines, Columbia University. Address, 66 West Forty-seventh Street, New York City.

WARE, WILLIAM R., B. S.

Professor of Architecture, School of Mines, Columbia University. Address, 126 East Twenty-eighth Street, New York City.

HONORARY MEMBERS DECEASED.

AGNEW, C. R.,	1888.
BARNARD, F. A. P.,	1889.
NEWBERRY, J. S.,	1892.
PECK, W. G.,	1892.
RUTHERFURD, LEWIS M.	1892.
TROWBRIDGE, W. P.,	1892.
FISH, HAMILTON,	1893.

LIST No 3.

Contains the names of Graduates of the School of Mines, not members of the Alumni Association, nor participating in the benefits of such membership. For this reason great uncertainty prevails as to many of the addresses given, which are the best at hand.

It is very desirable that this list should be shortened as far as practicable by the transfer of names from it to the preceding List, No. 2, under the Rules.

(Revised to March, 1897.)

Achen, J. B., Ph. B., ... 1894.
Haworth, N. J.

Adams, W. J., A. M., E. M., ... 1878.
Room 15, No. 132 Market St., San Francisco, Cal.

Adams, W. C., C. E., ... 1884.
47 W. 28th Street, New York City.

Agramonté, José Cesar, C. E., ... 1886.
Address unknown.

Agramonté, I, E., C. E., ... 1893.
Zulieta No. 3, Havana, Cuba.

Alden, Herbert C., E. M., ... 1884.
Address unknown.

Aldrich, C. H., Ph. B., ... 1893.
8 Cushing Street, Providence, R. I.

Anderson, George Mendenhall, Ph. B., ... 1891.
East Walnut Hills, Cincinnati, Ohio.

Andresen, Charles Alfred, E. M., ... 1881.
Pickard & Andresen, 89 Gold Street, New York City.

Appleby, John Storm, Ph. B., A. M., ... 1888.
Architect, 216 West Fifty-ninth Street, New York City.

Arden, John L., Ph. B., E. E., ... 1896.
Garrison, N. Y.

Aschman, Fred. Theo., Ph. B., ... 1881.
Chemist and Professor of Chemistry, College of Pharmacy,

Auryansen, Fredh., C. E., ... 1896.
Piermount, N. Y.
and 86 Water St., Pittsburg, Pa.

Ayestas, Alberto, Ph. B., ... 1883.
Tegucicalpa, Honduras, C. A.

Ayres, W. C., Ph. B., ... 1893.
Address unknown.

Bardwell, A. F., E. M., ... 1883.
Box 773, Aspen, Colo.

Barnard, Aug. Porter, E. M., ... 1868.
125 East Twenty-sixth Street, New York City.

Barros, Louis de Souza, E. M., C. E., ... 1877.
Address unknown.

Bartlett, F. R., C. E., ... 1880.
344 Madison Street, Brooklyn, N. Y.

Beckstein, Charles Alfred, Ph. B., ... 1888.
336 West Forty-sixth Street, New York City.

Beckwith, Charles Ellsworth, Met. Eng., ... 1888.
Address unknown.

Beckwith, George Alexander, C. E., ... 1890.
Paterson, N. J.

Behlen, Herman, Ph. B., ... 1890.
125 East One Hundred and Fifteenth Street, New York City.

Behr, Edward, C. E., ... 1877.
426 Henry Street, Brooklyn, N. Y.

Bell, Henderson M., Jr., E. M., ... 1886.
Bramwell, Mercer Co., W. Va.

Bergen, Chas. Hill, C. E., ... 1892.
Red Bank, N. J.

Berry, Gerald, C. E., ... 1889.
78 Morton Street, Brooklyn, N. Y.

Black, Alex. L., E. M., ... 1890.
56 Carondelet Street, New Orleans, La.

Bliss, Collins Pechin, Ph. B., ... 1891.
60 Cedar St., Room 9, New York City.

Bolles, Randolph, Ph. B., ... 1892.
Englewood, N. J.

Bolton, Robert, Ph. B., M. D., ... 1879.
Assistant Physician, Essex County Insane Asylum, So. Orange Av., Newark, N. J.

Bossange, E. R., Ph. B., ... 1893.
75 West Forty-fifth Street, New York City.

Brennan, Andrew Joseph, C. E., ... 1885.
Address unknown.

Bridgham, Samuel Willard, E. M., ... 1867.
49 West Twenty-third Street, New York City.

Brinckerhoff, George Charles, E. M., ... 1878.
Apartado 183, Matanzas, Cuba.

Bronson, Edward Stelle, A. B., A. M., E. M., ... 1867.
49 Garden Place, Brooklyn, N. Y.

Brooks, W. F., Ph. B., ... 1893.
335 West Fifty-fifth Street, New York City.

Bruckman, Frederick, E. M., ... 1869.
U. S. Mint, and 120 West Third Ave., Denver, Colo.

Buckingham, Frederick Endicott, E. M., ... 1884.
Department Public Works, Brooklyn, N. Y.

Buckland, Will A., Ph. B., ... 1890.
36 East Twenty-second Street, New York City.

Bullman, Chas., Ph. B., ... 1883.
808 3d Place, Plainfield, N. J.

Burrill, Percy M., E. M., ... 1896.
Bartow-on-Sound, N. Y., and 56 E. 49th Street, New York City.

Bush, William Falkner, E. M., ... 1885.
Address unknown.

Cairns, Fred. Irvan, Met. Eng., ... 1890.
20 Buckingham Avenue, Bridgeport, Conn.

Campbell, Alonzo Clarence, E. M., ... 1869.
Mining Engineer, 306 Russell Street, Nashville, Tenn. Specialty, Milling and Concentration.

Canfield, M. C., E. E., ... 1893.
18 Clinton Street, Cleveland, Ohio.

Carney, Edward J., C. E., ... 1896.
67 W. 68th Street, New York City.

Carrère, Joseph Maxwell, C. E., ... 1883.
36 Park Place, New York City, and New Brighton, N. Y.

Carson, Joseph, C. E., ... 1890.
31 West Fifty-fifth Street, New York City.

Cary, Geo. B., Ph. B., ... 1885.
184 Delaware Avenue, Buffalo, N. Y.

Chapman, A. W., E. E., A. B., ... 1894.
160 Hicks Street, Brooklyn, N. Y.

Chazel, P. E., ... 1881.
56–58 Broad Street, Charleston, S. Ca.

Clark, Leroy, Jr., E. E., ... 1894.
350 West Fiftieth Street, New York City.

Clayton, William Robert, Ph. B., ... 1890.
Architect, 31 and 32 Rialto Building, Chicago, Ill.

Cloud, Leo George, A. B., E. M., ... 1879.
216 Monmouth Street, Newport, Ky.

Colton, Frederick Gray, Ph., B., ... 1890.
136 Montague Street, Brooklyn, N. Y.

Colt, S. B., Ph. B. . . . . 1888.
1197 Broad Street, Newark, N. J.

Comstock, Claude Nichols, C. E., ... 1888.
Address unknown.

Constant, Charles Louis, E. M., C. E., ... 1877.
32 Park Street, Jersey City, N. J.

Cornell, George B., E. M., C. E., ... 1877.
29 Broadway and 46 West 48th Street, New York City.

Cornwall, George Rockwell, E. M., C. E., ... 1876.
189 Lefferts Place, Brooklyn, N. Y.

Coursen, George Hampton, E. M., C. E., ... 1868.
Address unknown.

Covell, E. C., A. B., ... 1892.
Address unknown.

Covell, W. S., Ph. B. . . . . 1893.
42 West Sixty-sixth Street, New York City.

Coykendall, Thomas Cornell, C. E., ... 1890.
Rondout, N. Y.

Cozzens, Harmon, E. M., ... 1885.
Address unknown.

Cristy, Edward Buxton, Ph. B., ... 1891.
Albuquerque, New Mexico.

Cromwell, James William, Jr., Ph. B., ... 1889.
Architect, 29 Brevoort Place, Brooklyn, N. Y.

Crowell, Charles B., Ph. B., ... 1885.
Minneapolis, Minn.

Curtis, Charles Gordon, C. E., ... 1881.
President Curtis Electrical Mfg. Co., Whiton St., Jersey City, N. J.

Curtiss, C. C., A. B., A. M., ... 1892.
Address unknown.

Darrach, J. M. A., Ph. B., ... 1896.
Morristown, N. J.

Davis, William Monroe, E. M., ... 1890.
Syracuse, N. Y.

Del Calvo, Francis, C. E., ... 1884.
Address unknown.

Detwiller, Charles Henry, Ph. B., ... 1885.
Detwiller & Melendy, 97 Nassau Street, New York City, and 56 Danforth Avenue, Jersey City, N. J.

Dodsworth, W. A., Ph. B., ... 1888.
19 Beaver Street, New York City.
Doolittle, Charles Horace, E. M., ... 1885.
Address unknown.
Dowie, Horace, A. B., E. E., ... 1896.
363 Jefferson Ave., Brooklyn, N. Y.
Downing, Orrien Pinkerton, Ph. B., ... 1878.
116 Battery Street, San Francisco, Cal.
Dunn, Gano Sillick, B. S., E. E., ... 1891.
Elect. Engineer, Crocker-Wheeler Electric Co., Ampere, East Orange, N. J.
Durham, Edward B., E. M., ... 1892.
Mt. Kisko, N. Y.
Eliot, Walter Greame, E. M., C. E., Ph. B., Ph. D., ... 1878.
"University Magazine," 70 South St., and University Club, N. Y. City.
Ellis, A. Van Horn, C. E., ... 1889.
Bartow-on-Sound, N. Y.
Emanuel, L. V., C. E., ... 1896.
925 Park Avenue, New York City.
Emery, H. G., Ph. B., ... 1894.
Nyack, N. J.
Escobar, Francisco, E. M., ... 1889.
842 Wilson Avenue, Cleveland, Ohio.
Fales, William, E. S., E. M., LL. B., ... 1871.
Amoy, China.
Fellows, William K., Ph. B., ... 1894.
7818 Eggleston Avenue, Chicago, Ill.
Fenner, Clarence Norman, E. M., ... 1892.
Paterson, N. J.
Ferguson, George Albert, Ph. B., ... 1890.
138 Wilson Street, Brooklyn, N. Y.
Fisher, Lloyd Wiegand, Ph. B., ... 1890.
109 E. Twenty-eighth Street, New York City.
Fitch, Charles Lincoln, E. M., ... 1882.
Address unknown.
Fitch, Josiah Huntingdon, E. M., ... 1884.
Address unknown.
Fitzgerald, George E., E. M., ... 1884.
El Paso, Texas.
Francke, Robert Otto, C. E., ... 1880.
W. Passburg, Esq., Moscow, Russia.
Frankfield, Emil, C. E., ... 1886.
328 W. Fifty-sixth Street, New York City.
Franklin, L. M.. Jr., Ph. B., ... 1896.
Flushing, L. I., N. Y.
Frisbee, H. D., E. E., ... 1894.
Fulton Street, New York City.
Fuentes, Paul, E. M., ... 1894.
321 Hudson Street, Hoboken, N. J.
Gage, Samuel Edson, Ph. B., ... 1887.
Architect, 114 Fifth Avenue, New York City.

Gardner, Watts Denning, C. E., ... 1888.
Board of Health, New York City.

Garrison, Edmund Hoyt. E. M., C. E., ... 1876.
84 Highland Street, Yonkers, N. Y.

Geer, George Jarvis, Jr., E. M., ... 1868.
Merchant, 453 Broome Street, New York City.

Giddings, Edward Everett, E. M., ... 1867.
Merchant, 413 Royal Insurance Building, Chicago, Ill.

Goldsmith, Byron Benjamin, Ph. B., ... 1887.
19 East Seventy-fourth Street, New York City.

Goldsmith, Goldwin, Ph. B., ... 1896.
New Rochelle, N. Y.

Gould, Edward Ludlow, C. E., ... 1890.
59 Hawthorne Avenue, Yonkers, N. Y.

Greene, Wilkins Updike, Ph. B., ... 1880.
104 Columbia Heights, Brooklyn, N. Y.

Gregory, L. E., C. E., ... 1893.
406 Passaic Avenue, Kearney, N. J.

Griffin, S. P., Jr., ... 1884.
449 Park Avenue, New York City.

Griffith, Vincent Colyer, Ph. B., ... 1889.
160 Herkimer Street, Brooklyn, N. Y.

Griggs, Wilfred Elizur, Ph. B., ... 1889.
Architect, Waterbury, Conn.

Haas, Harry Leopold, Ph. B., ... 1878.
Carrère and Haas, 36 Park Place, New York City.

Hamilton, Schuyler, Jr., A. B., A. M., E. M., ... 1876.
Croton-on-Hudson, Westchester, Co., N. Y., Architect and Brick M'f'r.

Hanson, R. C., C. E., ... 1894.
79 Manhattan Avenue, New York City.

Harker, Charles Sumner, E. M., ... 1879.
26 Montgomery Street, San Francisco, Cal.

Harmer, Thomas Hayes, A. B., A. M., E. M., ... 1867.
113 East Twenty-seventh Street, New York City.

Harrison, Newton, E. E., ... 1892.
Electrical Engineer, 136 Liberty Street, New York City.

Hart, Burnham, C. E., ... 1885.
Ramsay, N. J.

Hart, Charles Henry, C. E., ... 1890.
199 Lenox Avenue, New York City.

Hasegawa, Yothinosuke, E. M., Ph. D., ... 1878.
Mitsu Bishi Sha, No. 11, Awajicho, Nichome Kanda, Tokio, Japan.

Hawkes, Emil MacDougal, A. B., E. M., ... 1885.
267 Fifth Avenue, New York City.

Hawks, H. D., E. E., ... 1896.
40 W. 55th Street, New York City.

Hay, Arthur, E. M., ... 1892.
821 South Second Street, Springfield, Ill.

Heinze, Frederick Augustus, E. M., ... 1889.
General Manager, Montana Ore Purchasing Co., Butte, Montana.

Hesselbach, Chas. V., C. E., ... 1896.
93 Lexington Avenue, New York City.
Hemmer, Frederick Adolph, Ph. B., ... 1881.
Box 6, Edgewater, N. J.
Heye, Geo. G., E. E., ... 1896.
11 E. 48th Street, New York City.
Hooper, Louis Mosher, C. E., ... 1880.
Rutherford, N. J.
Holter, Norman Bernard, E. M., ... 1891.
A. M. Holter Hardware Co., Helena, Mont.
Horn, James Thurston, A. B., C. E., ... 1884.
Naval Architect, and 13 E. Fifty-third Street, New York City.
Hornbostel, Henry Frederick, Ph. B., ... 1891.
39 Second Place, Brooklyn, N. Y.
Hoyt, John Sherman, C. E., ... 1890.
934 Fifth Avenue, New York City.
Hoyt, R., C. E., ... 1893.
Katonah, N. Y.
Hoyt, W. L., C. E., ... 1876
Globe Smelting and Refining Co., Denver, Colo.
Hudson, Edward Henry, C. E., ... 1880.
Address unknown.
Huntting, Henry Ogden, Ph. B., ... 1887.
Architect, 454 Ceasson Avenue, Brooklyn, N. Y.
Hyatt, Chas. Edwd., E. E., ... 1896.
Newark, N. J.
Ihlseng, M. C., C. E., Ph. D., ... 1875.
State College, Pa.
Ives, Arthur Stanley, C. E., E. E., ... 1889.
33 Sidney Place, Brooklyn, N. Y.
Jackson, Charles Edward, C. E., ... 1875.
15 Courtland Street, New York City.
Jacobs, H. H., Ph. B., ... 1894.
107 E. Seventy-eighth Street, New York City.
Jarmulowsky, Meyer, Ph. B., ... 1890.
27 Jefferson Street, New York City.
Joffe, Mayer, C. E., ... 1894.
Verona, N. J.
Jenney, Walter Proctor, E. M., Ph. D., ... 1869.
Rapid City, South Dakota.
Jones, E. M., C. E., ... 1894.
312 W. Twenty-eighth Street, New York City.
Jones, Thomas John, Met. Eng., ... 1890.
Pulaski City, Va.
Jordao, Jose Nabor Pacheco, C. E., E. M., Ph. B., ... 1877.
Address unknown.
Judd, Charles Breck, E. M., ... 1881.
Westinghouse Building, Pittsburg, Pa.
Karr, C. P., Ph. B., ... 1878.
1 Union Square, West, New York City.

Keeler, Frederick Sterling, Ph. B., ... 1891.
530 Bouch Avenue, Buffalo, N. Y.
King, Charles, Ph. B. . . . . 1876.
Railroad contractor, King & Dickinson, Tacoma, Wash.
Kletchka, John Joseph, A. B., C. E., ... 1892.
247 Willis Avenue, New York City.
Knapp, John Augustus, A. B., A. M., E. M., ... 1870.
Chicago and Aurora Smelting Co., Chicago, Ill.
Knox, Charles E., E. E., ... 1892.
Jas. W. Queen & Co., Philadelphia, Pa.
Kohn, Robert David, Ph. B., ... 1890.
4 Rue Honoré Chevalier, Paris, France.
Korn, Louis, Ph. B., ... 1890.
261 Broadway, New York City.
Ledoux, Augustus Damon, Ph. B., ... 1881.
P. O. Box 426, Richmond, Va.
Lee, Henry Charles, C. E., ... 1886.
127 East Twenty-first Street, New York City.
Lichtenstein, Edward Gervaise, Ph. B., ... 1890.
14 W. Seventy-fourth Street, New York City.
Lindsley, Stewart, E. M., ... 1870.
Orange, N. J.
Livingston, Goodhue, Ph. B., ... 1892.
Geo. B. Post, Century Bldg., New York City.
Lord, Nathaniel Wright, E. M., ... 1876.
Professor Mining and Metallurgy, Ohio State University, Columbus, O.
Lowndes, William Shepherd, Ph. B., ... 1890.
42 Sherman Place, Jersey City, N. J.
McDowell, Frederick H., E. M., ... 1872.
Address unknown.
McIlvaine, Alexis Reed, Ph. B., ... 1888.
Architect, 48 Exchange Place, New York City.
McKee, H. S., E. M., ... 1893.
Los Angeles Terminal Railway Co., Los Angeles, Cal.
McKinlay, James Buell, E. M., ... 1892.
108 W. Seventy-ninth Street, New York City.
McKleroy, William Henry, Met. Eng., ... 1890.
Cashier Anniston National Bank, Anniston, Ala.
McNeil, Charles R., Ph. B., ... 1894.
Litchfield, Conn.
MacGahan, Paul, E. E., ... 1896.
75 East 61st Street, New York City.
MacGregor, Donald, Ph. B., ... 1896.
1118 Madison Avenue, New York City.
Macy, V. E., Ph. B., ... 1893.
18 West Fifty-third Street, New York City.
Maghee, John Holme, A. B , A. M., C. E., ... 1876.
Cayuga Lake Ice Line, Rochester, N. Y., and 29 East Thirty-second Street, New York City.
Mahl, J. Thomas, C. E., ... 1891.
G. H. & S. A. R. R. Co., Houston, Texas.

Mann, C. R., A. B., A. M., ... 1891.
Address unknown.
Mann, Horace Borchsenius, Ph. B., ... 1890.
Orange, N. J.
Mapes, Charles Halstead, Ph. B., ... 1889.
60 West Fortieth Street, New York City.
Marsh, Charles Wells, Ph. B., Ph. D., ... 1879.
435 Fifth Avenue, New York City.
Matthews, Charles Thompson, Ph. B., ... 1889.
Architect, Elm Park, Norwalk, Conn.
Matthew, W. D., Ph. B., ... 1893.
St. John, N. B., Canada.
Matsui, Nawokichi, Ph. B., Ph. D., ... 1878.
Agricultural College, Konaba, Tokio, Japan.
Mattison, Joseph Godley, Ph. B., ... 1880.
Real Estate and Insurance Broker, 20 W. Fourteenth Street, New York City.
Meikleham, Thomas Mann Randolph, C. E., ... 1890.
Address unknown.
Merwin, H. J., E. M., ... 1879.
Middlesborough, Ky.
Mesa, Antonio Esteban, C. E., ... 1882.
Address unknown.
Mears, George K., E. E., ... 1894.
Elizabeth, N. J.
Metzger, Arthur, Ph. B., ... 1896.
43 East 72d Street, New York City.
Moeller, Rudolph, Ph. B., ... 1887.
336 West Twenty-ninth Street, New York City.
Monell, Ambrose Jr., E. E., ... 1896.
43 Lafayette Place, New York City.
Montgomery, H. P. A., Ph. B., ... 1896.
1189 Madison Avenue, New York City.
Morgan, J. L., Ph. B., ... 1888.
47 Fulton Street, New York City.
Morewood, George Barrow, E. M., Ph. D., ... 1878.
156 West Seventy-sixth Street, New York City.
Morewood, Henry Francis, E. M., Ph. D., ... 1876.
Importer, Box 2087, New York City.
Morris, B. W., Jr., Ph. B., ... 1894.
33 West Forty-second Street, New York City.
Morse, Geo. T., Ph. B., ... 1896.
613 Carleton Avenue, Brooklyn, N. Y.
Munoz del Monte, A. C., C. E., Ph. D., ... 1888.
328 Chestnut Street, Philadelphia, Pa.
Munroe, M., E. E., ... 1894.
Address unknown.
Murray, George, E. M., ... 1874.
235 West Twenty-third Street, New York City.
Murchison, K. M., Jr., Ph. B., ... 1894.
46 West Fifty-seventh Street, New York City.

Nambu, Kingo, E. M., ... 1878.
Nagasaki, Japan.

Nettre, L. R., E. M., ... 1869.
26 Coventry Street W., London, England.

Necarsulmer, Edwd., Ph. B., ...
109 East 70th Street, New York City.

Newton, T. M., Ph. B., ... 1893.
40 West Seventy-fifth Street, New York City.

Neymann, Percy, Ph. B., Ph. D., ... 1881.
Chemist and Assistant Superintendent, 36 Michigan Street, Cleveland, O.

Nicholas, Harry Parmelee, E. M., ... 1887.
Hotel St. George, 49 East Twelfth Street, New York City.

Noble, Charles Milton, E. M., ... 1879.
Manager Ruttan Mfg. Co., Anniston, Ala.

Oakes, J. C., B. S., Ph. B., ... 1893.
423 West Twenty-first Street, New York City.

Oseranski, Isaac Henry, C. E., ... 1889.
Address unknown.

Owens, Robert Bowie, E. E., ... 1892.
Professor Elect. Engineering, University of Nebraska, Lincoln, Neb.

Oxnard, James Guerrero, Ph. B., ... 1883.
Norfolk, Neb.

Painter, Robt. K., E. M., ... 1896.
5 Union Street, New Brunswick, N. J.

Palmer, Cortlandt Edward, E. M., ... 1878.
Colorado Springs, Colo.

Palmer, Geo. A., C. E. . . . . 1896.
922 5th Avenue, New York City.

Parmly, Chas. Howard, B. S., E. E., ... 1892.
344 W. Twenty-ninth Street, New York City.

Parsons, H. A., C. E., ... 1894.
South Norwalk, Conn.

Parsons, George H., E. M., ... 1868.
Colorado Springs, Colo.

Pazos, Vincent Felix, E. M., ... 1878.
Address unknown.

Pearce, R., Ph. D., ... 1890.
Address unknown.

Pederson, F. M., B. S., E. E., ... 1893.
327 W. Thirty-fourth Street, New York City.

Pelton, H. C., Ph. B., ... 1890.
Address unknown.

Pemoff, Joel., C. E., ... 1896.
244 East Broadway, New York City.

Perry, Nelson W., E. M., ... 1878.
Editorial Staff "Electrical World," New York City.

Perry, Chas. L., E. E., ... 1896.
14 Hampden Street, New York City.

Pfister, Philip Charles, E. M., ... 1875.
Address unknown.

Pierce, Harry Nelson, E. M., ... 1885.
Address unknown.

Platt, Charles Slason, E. M., ... 1868.
Assayer, 21 and 31 Gold Street, New York City.

Pomeroy, W. A., E. M., ... 1893.
Oswego, Oregon.

Pope, J. R., Ph. B., ... 1894.
111 E. Twenty-fifth Street, New York City.

Portuondo, Jose, C. E., ... 1890.
San Basilio, Alta 28, Santiago, Cuba.

Post, A. Van Zo, C. E., ... 1889.
45 Wall Street, New York City.

Post, R. B., Ph. B., ... 1893.
Elizabeth, N. J.

Post, William Stone, Ph. B., ... 1890.
Bernardsville, N. J.

Powers, Cornelius Van Vorst, Ph. B., ... 1882.
Assistant Engineer Aqueduct, Katonah, N. Y.

Primelles, Jose Alejandro, C. E., ... 1887.
Mercedes 23, Puerto Principe, Cuba.

Prince, A. D., C. E., ... 1893.
30 W. Forty-seventh Street, New York City.

Proctor, William Ross, E. M., ... 1884.
43 and 45 Sixth Avenue, Pittsburg, Pa.

Provot, F. A., C. E., ... 1893.
Box 166, Orange Valley, N. J.

Provot, George, Ph. B., ... 1889.
Architect, 24 Highland Terrace, Orange, N. J.

Radford, William Helsham, E. M., ... 1877.
Lydenburgh Gold Mining Co., Limited, Manchester, Eng.

Randolph, Edmund, Ph. B., ... 1883.
E. & C. Randolph, 7 Nassau St., New York City; also Knickerbocker Club.

Raymer, George Sharp, A. B., E. M., ... 1881.
Mine Superintendent, Idaho Springs, Colorado, and 63 Seventh Avenue, Brooklyn, N. Y.

Raymond, Alfred, Ph. B., ... 1891.
123 Henry Street, Brooklyn, N. Y.

Raymond, Wm. O., Ph. B., ... 1896.
31 East 82d Street, New York City.

Reed, William Bell Stephen, E. M., ... 1879.
Helena, Mont.

Rees, B. F., E. M., ... 1874.
Chattanooga, Tenn.

Reese, William W., A. B., E. E., ... 1892.
New Hamburg, N. Y.

Regan, Geo. W., E. E., ... 1896.
352 Degraw Street, Brooklyn, N. Y.

Rennard, John C., E. E., ... 1894.
302 W. Seventy-third Street, New York City.

Reynolds, M. T., A. B., Ph. B., ... 1893.
98 Columbia Street, Albany, N. Y.

Richmond, William Thomas, Ph. B., ... 1881.
68 Thomas Street, New York City.
Riedel, A. E., E. E., ... 1896.
146 Delaney Street, New York City.
Riggs, Geo. Washington, Ph. B., ... 1871.
Summit, N. J.
Rittenhouse, Charles T., E. E., ... 1894.
247 W. 138 Street, New York City.
Roberts, Arthur Carr, E. M., ... 1881.
Address unknown.
Roberts, Gracie Sayre, E. M., C. E., ... 1871.
Sewer Bureau, Dept. City Works, Brooklyn, N. Y.
Robertson, Kenneth, E. M., ... 1868.
General Manager West Superior Iron and Steel Co., W. Superior, Wis.
Robertson, Richard Spotswood, Jr., E. M., ... 1871.
Jackson, Minn.
Robinson, F. G., E. E., ... 1893.
Superintendent Amsterdam Street Railway, Amsterdam, N. Y.
Robinson, Henry Alvord, Ph. B., ... 1880.
Lawyer, 150 Broadway, New York City.
Rogers, Charles Louis, E. M., C. E., ... 1877.
823 Broad Street, Chattanooga, Tenn.
Rood, R. G., Ph. B., ... 1884.
Care Prof. O. N. Rood, Columbia University, New York City.
Ross, William Coleman, C. E., E. M., ... 1876.
Address unknown.
Rutherford, Lewis Hopkins, E. M., ... 1887.
Franklin, Pa.
Sanders, Wilbur Edgerton, E. M., ... 1885.
Mine Supt., Ewing and Seventh Avenue, Helena, Mont.
Savage, Seward Merrill, C. E., ... 1892.
2260 Pacific Street, Brooklyn, N. Y.
Sawyer, Charles Pike, Ph. B., ... 1881.
Address unknown.
Sergeant, E. M., E. E., ... 1896.
Summit, N. J.
Shack, Albert P., E. M., ... 1868.
Address unknown.
Serber, David C., C. E., ... 1896.
271 East Broadway, New York City.
Sherman, C. F. G., C. E., ... 1894.
1138 Seventh Street, Boisé City, Idaho.
Shire, Edwd. I., Ph. B., ... 1896.
109 East 61st Street, New York City.
Shope, Henry Brengle, Ph. B., ... 1885.
19 West Thirty-second Street, New York City.
Skidmore, Samuel Tredwell, A. B., Ph. B. . . . . 1889.
71 West Fiftieth Street, New York City.
Slichter, W. I., E. E., ... 1896.
127 W. 58th Street, New York City.

Sloane, Thomas O'Connor, A. B., A. M., E. M., Ph. D., ... 1872.
South Orange, N. J.

Small, Franklin Maurice, Ph. B., ... 1889.
Architect, 199 Second Avenue, New York City.

Smeaton, William Henry, C. E., E. M., ... 1877.
15 Horatio Street, New York City.

Smedberg, Henry Ashton, A. B., C. E., ... 1884.
347 Fifth Avenue, New York City.

Smith, H. A., Ph. B., ... 1893.
460 West Forty-fourth Street, New York City.

Smith, Maxwell, C. E., ... 1880.
Adon Smith, 8 Bridge Street, New York City.

Smyth, Roland Mulvill, E. M., C. E., ... 1877.
452 Produce Exchange, New York City. 1879 to date, banker and broker.

Speyers, Clarence Livingston, Ph. B., ... 1884.
Associate Professor Chemistry, Rutgers College, New Brunswick, N. J.

Stallnecht, Frederick, E. M., ... 1868.
Editor, 11 Bond Street, New York City.

Starr, Henry Fowler, Ph. B. . . . . 1879.
91 Mt. Pleasant Avenue, Newark, N. J.

Steers, James Rich, Ph. B., ... 1890.
10 East Thirty-eighth Street, New York City.

Stern, Henry, Ph. B., ... 1896.
230 East 69th Street, New York City.

Steinam, J. L., Ph. B., ... 1894.
31 W. Ninety-fifth Street, New York City.

Stevens, Alexander, C. E., ... 1887.
No. 1 Newark St., Hoboken, N. J.

Stewart, Hunter, E. M., ... 1875.
Address unknown.

St. John, Thomas Matthew, Met. Eng., ... 1890.
New York City.

Stoughton, Arthur Alexander, Ph. B., ... 1888.
1665 Washington Avenue, New York City.

Stoughton, Charles William, C. E., ... 1889.
1665 Washington Avenue, New York City.

Stratton, Alex., E. E., ... 1894.
2013 Fifth Avenue, New York City.

Strieby, William, A. M., E. M., ... 1878.
Professor of Metallurgy and Assaying, Colorado College, Colorado Springs, Colo.

Strout, William Allen, Ph. B., ... 1891.
366 Carlton Avenue, Brooklyn, N. Y.

Suydam, John Richard, Jr., E. M., ... 1879.
14 East Forty-first Street, New York City.

Tachan, Wm. G., Ph. B., ... 1896.
Louisville, Ky.

Tennille, George F., Ph. B., ... 1894.
Central Lard Co., 519 West Thirty-third Street, New York City.

Thomas, Franz Charles, Ph. B., ... 1891.
Address unknown.

Thompson, Milton Strong, Ph. B., ... 1875.
Chemist, Newburyport, Mass.

Thompson, S. C., A. B., E. M., ... 1893.
Grass Valley, Nevada Co., Cal.

Thorne, William Lincoln, Ph. B., ... 1890.
63 High Street, Yonkers, N. Y.

Thyng, Wm. S., E. M., ... 1896.
Deerfield, Mass.

Tilghman, H. A., E. M., ... 1893.
Sanslito, Cal.

Toch, Max B., Ph. B., ... 1896.
34 W. 92d Street, New York City.

Tompkins, J. A., Ph. B., ... 1894.
Address unknown.

Totten, George Oakley, Jr., Ph. B., (1892) . . . . . 1891.
62 North Eleventh Street, Newark, N. J.

Toucey, Donald Butler, LL. B., E. M., ... 1882.
743 Madison Avenue, New York City.

Towart, James, C. E., ... 1892.
Box 296, Peekskill, N. Y.

Trowbridge, Samuel Breck Parkman, A. B., Ph. B., ... 1886.
Architect, 7 East Forty-sixth Street, New York City.

Tubby, J. T., Jr., Ph. B., ... 1896.
67 Willow Street, Brooklyn, N. Y.

Tucker, Allen, Ph. B., ... 1888.
80 Washington Square E., New York City. .

Tucker, John Henry, Ph. B., Ph. D., ... 1875.
Globe Smelting and Refining Co., Denver, Colo.

Tuttle, W., Ph. B., ... 1893.
520 Summer Avenue, Newark, N. J.

Tuttle, William W., E. M., ... 1867.
Springfield, Mo.

Uhlig, Wm. C., Ph., B., ... 1896.
229 E. 12th Street, New York City.

Van Benthuysen, Boyd, Ph. B., ... 1896.
Albany, N. Y.

Van Boskerck, Robert Ward, E. M., ... 1877.
Artist, 58 West Fifty-seventh Street, New York City.

Van Brunt, Arthur Hoffman, Ph. B., ... 1886.
Architect, 54 Wall Street, New York City.

Van Ingen, Dudley Arthur, Ph. B., ... 1892.
135 Henry Street, Brooklyn, N. Y.

Van Lennep, David, E. M., ... 1868.
Auburn, Placer County, Cal. Fruit ranch.

Van Gelder, A. P., Ph. B., ... 1896.
Catskill, N. Y.

Van Vlech, Jos., Jr., Ph. B., ... 1896.
Montclaire, N. J.

Vanderbilt, W. D., C. E., ... 1894.
44 Monroe Place, Brooklyn, N. Y.

Vatable, J. J., Ph. B., ... 1894.
89 Water Street, New York City.
Wainwright, Richard Tighe, C. E., ... 1890.
Rye, N. Y.
Wallace, William J., Ph. B., ... 1886.
Whitestone, N. Y.
Wallbridge, Frederick Kidder, E. M., ... 1884.
37 Ninth Avenue, Brooklyn N. Y.
Walker, Joseph, Jr., C. E., ... 1880.
112 East Thirty-seventh Street, New York City.
Wanier, Albert George, Ph. D., ... 1882.
Kreisherville, Staten Island, N. Y.
Ward, Norbert Reillieux, E. M., ... 1882.
Morgan Furn. Co., 1180 Broadway, New York City.
Ware, F. B., Ph. B., ... 1894.
1285 Madison Avenue, New York City.
Warren, Charles Peck, Ph. B., A. M. (1892), ... 1890.
286 Clifton Place, Brooklyn, N. Y.
Warren, Lloyd, Ph. B., ... 1891.
520 Fifth Avenue, New York City.
Waterbury, Cornelius Reed, C. L., C. E., LL. B., ... 1877.
Lawyer, 45 Broadway, New York City.
Waters, George Safford, Ph. B., ... 1889.
Architect, Andrews, Waters & Sherwin, 42 W. Forty-third St. N. Y. City.
Webb, Henry Walter, E. M., LL. B., ... 1873.
Third Vice-President, N. Y. C. & H. R. R. R., and 15 West Forty-seventh Street, New York City.
Wells, D. C., E. E., A. B., ... 1896.
109 Willow Street, Brooklyn, N. Y.
Wels, Paul O., E. M., B. S., ... 1887.
Boston & Montana Co., Great Falls, Mont.
Welsh, Howard Farrington, E. M., ... 1890.
Mingo Mountain Coal and Coke Co., Hartranft, Tenn.
Werner, Henry Clay, Ph. B., ... 1892.
120 East Sixty-fifth St., New York City.
Wetmore, Edwin Atwater, E. M., ... 1875.
Iron Merchant, Marquette, Mich.
Wheatley, Joseph Yendes, C. E., ... 1886.
Whitesboro, N. Y.
White, Wm. Sherf, E. M., ... 1882.
430 Gold Street, Brooklyn, N. Y.
Whitman, Edmund Pineo, E. M., ... 1885.
50 Beacon Street, Boston, Mass.
Williams, Frederick Harrison, E. M., ... 1874.
Riverside Iron Works, and 34 Virginia Street, Wheeling, W. Va.
Wilson, Clarence Edgar, Ph. B., ... 1886.
Address unknown.
Windecker, Clifton Nicholas, C. E., ... 1892.
33 Sidney Place, Brooklyn, N. Y.
Witherel, Chas. S., Met. E., ... 1896.
Greenwich, Conn.

Wood, George E., E. M., Ph. B., ... 1884.
Architect, 63 William Street, New York City.
Woodruff, Geo. W. L., Ph. B., E. E., ... 1896.
27 East 22d Street, New York City.
Wright, Albert Allen, A. M., Ph. B., ... 1875.
Professor of Geology and Natural History, Oberlin College, Oberlin, Ohio.

LIST No. 4.

Contains the Names of Members of the Alumni Association classified territorially by residence. Those not Members of the Association are not included by reason of the uncertainty as to address of such persons.

(Revised to March, 1897.)

Alabama.—*Henry Ellen*, J. J. Ormsbee; *Tuscaloosa*, S. Friedman.

Arizona.—*Congress*, W. F. Staunton; *Harqua Hala*, R. M. Raymond; *Pearce*, G. F. Reckhart.

California.—*Bodie*, R. G. Brown; *Los Angeles*, W. F. Brugman; *Napa City*, E. Goodwin; *Palo Alto*, L. R. Lenox; *San Francisco*, L. C. Easton, D. E. Mellis, E. C. Van Blarcom; *Selby*, E. N. Engelhardt; *Stockton*, E. F. Haas.

Colorado.—*Aspen*, C. W. Miller; *Boulder*, B. C. Hinman; *Colorado Springs*, W. E. Newberry; *Crested Butte*, Frederick Bayles; *Cripple Creek*, F. C. Hamilton; *Denver*, H. V. F. Furman, M. W. Iles, C. F. Lacombe, B. B. Lawrence, G. A. Schroter, T. B. Stearns, F. M. Thomas, E. N. Van Cortlandt, T. F. Van Wagenen; *Durango*, E. J. H. Amy; *Glenwood Springs*, W. B. Devereux; *Leadville*, Geo. B. Lee, E. H. Messeter; *Pueblo*, A. S. Dwight, E. C. Eddy, H. E. Eilers, M. B. Holt; *State College*, M. C. Ihlseng; *Telluride*, T. F. Van Wagenen.

Connecticut.—*Collinsville*, W. Hill.

Delaware.—*Wilmington*, H. G. Haskell.

District of Columbia.—*Washington*, E. C. Barnard, J. S. Cox, Jr., E. M. Douglas, A. W. Dow, H. W. Durham, W. T. Griswold, H. Hollerith, F. W. Tower, W. H. Weed, B. Willis, H. M. Wilson.

Georgia.—*Savannah*, D. B. Falk.

Illinois.—*Carthage*, J. C. Ferris; *Chicago*, E. G. Barratt, S. S. Fowler, H. L. Hollis, C. L. Miller, S. B. Peck, F. B. F. Rhodes, W. H. Van Arsdale, L. Wampold; *Aurora*, F. H. Jobbins.

Idaho.—*Moscow*, E. Goodwin; *Rocky Bar*, E. C. Koch.

Indiana.—*Indianapolis*, B. J. T. Jeup; *Muncie*, J. R. Marsh.

Indian Territory.—*Hartshorn*, E. Ludlow.

Iowa.—*Davenport*, F. P. Bemis, E. Gudeman; *Ottumwa*, S. S. Rice.

Kansas.—*Argentine*, H. Garlichs.

Louisiana.—*New Orleans*, A. L. Black, G. S. Eastwick, E. P. Eastwick.

Maryland.—*Baltimore*, A. L. Walker; *Glencoe*, E. A. McCulloh.

Massachusetts.—*Boston*, Francis Blossom, C. R. Harte, A. J. Malukoff; *Cambridge*, J. A. Noyes; *New Bedford*, N. Hathaway, W. F. Williams; *Springfield*, L. J. Powers.

Michigan.—*Houghton*, R. M. Edwards, F. McM. Stanton; *Marquette*, R. A. Parker; *Trenton*, E. D. Church; *Vulcan*, W. Kelley.

Minnesota.—*Minneapolis*, W. R. Appleby, F. W. Denton; *Soudon*, C. B. Crowell.

Missouri.—*Carthage*, A. O. Ihlseng; *De Soto*, O. M. Munroe; *Poplar Bluff*, E. A. Harris; *St. Louis*, W. B. Potter, E. Starek, A. Thacher, H. A. Wheeler.

Montana.—*Bozeman*, F. W. Traphagen; *Butte*, F. Sands; *Great Falls*, F. Kleptko; *Helena*, W. H. Aldridge, H. M. Cole, P. A. L. Mannheim, J. R. Parks, C. F. Pearis; *Smelter*, A. F. Emrich, F. M. Smith-

Nevada.—*Delamar*, R. Nichols.

New Jersey.—*Bayonne*, C. P. Bleecker; *Bloomfield*, N. Butler, Jr.; *Dover*, F. A. Canfield; *Englewood*, W. W. Burritt; *Fort Lee*, C. G. Massa; *High Bridge*, C. Le Boutillier; *Jersey City*, J. R. Binion, W. F. Downs; P. C. McIlhiney, H. Pinkham, R. H. Vondy; *Mamaroneck*, F. P. Smith; *Maurer*, C. H. Joüet; *Morristown*, J. R. Brinley, J. P. Pennington, J. F. Randolph; *Newark*, H. G. Atha, C. A. Colton, C. E. Graff, A. W. Jenk, F. W. Kinsey, Jos. Lowenstine, E. Merz, H. M. Murphy, G. C. Stone, F. Vanderpoel, E. Waller, W. Wiener; *New Brunswick*, A. H. Chester, W. D. Horne; *Orange*, R. K. Mosley; *Passaic*, E. W. Guiterman; *Paterson*, L. D. Huntoon; *Perth Amboy*, D. F. Haasis, A. F. Schneider; *Plainfield*, F. A. Cokefair; *Princeton*, H. B. Cornwall; *South Orange*, E. D. Self; *Trenton*, J. H. Janeway, F. E. Pierce; *Waverly*, A. C. Langmuir.

New York.—*Albany*, F. J. H. Merrill; *Brooklyn*, R. L. Allen, P. T. Austen, G. W. Behrman, G. Berry, F. Blossom, D. D. Book, G. H. Casamajor, J. S. Cox, E. P. Clark, J. T. Corcoran, J. A. Deghnée, F. D. Dodge, H. W. Durham, W. L. Dusenberry, L. G. Engle, E. P. Folger, A. D. Granger, S. A. Goldschmidt, W. A. Herkenwrath, J. M. Hewlett, E. D. Hurlburt, F. S. Hyde, W. D. Jones, F. Lyman, J. H. Merrett, W. M. Meserole, J. Middleton, J. Nesmith, T. S. Perkins, F. E. Pierce, W. E. Preston, H. A. Prosser, A. J. Provost, C. B. Rowland, G. Rowland, R. Seldver, W. W. Share, L. R. Shattuck, E. Skinner, G. C. Southard, G. A. Tibbals, S. G. Tibbals, W. L. Tyler, W. B. Vanderbilt, E. Van Dyck, G. J. Volckening, E. R. Von Nardroff, H. V. Walker; *Buffalo*, E. L. Ingram; *Cazenovia*, H. Burden, 2d; *Clifton*, F. R. Lord; *Clinton*, C. H. Smyth; *Flushing*, M. T. Bogert; *Laurel Hill*, W. C. Ferguson; *Locust Valley*, L. H. Vaile; *New Brighton*, A. Hollick, W. B. Johnson; *New Rochelle*, L. P. De Luze, F. P. Smith; *New York City*, F. E. Agramonte, S. W. Andrews, L. A. Ansbacher, A. Anthony, S. W. Balch, W. M. Baldwin, J. H. Banks, L. H. Barnett, G. S. Baxter, Chas. A. Bechstein, A. L. Beebe, W. L. Benedict, F. P. Benjamin, M. Benjamin, S. D. Benoliel, W. G. Berry, J. R. Bien, A. Black, E. M. Blake, O. Bodelsen, W. Boecklin, Jr., S. Bookman, R. E. Booraem, R. C. Boyd, S. R. Bradley, N. L. Britton, H. D. Brewster, F. X. Brosnan, F. G. Brown, W. Bryce, C. R. Buckley, A. L. Burns, E. R. Bush, N. Butler, W. P. Butler, L. B. Cady, A. Calman, E. P. Casey, J. P. Carson, J. B. Cauldwell, C. F. Chandler, J. P. Channing, J. A. Church, A. J. Clark, Edmund Clark, G. H. Clark, C. E. Colby, S. B. Colt, H. C. Cornwall, F. B. Croker, A. R. Cushman, H. G. Darwin, C. H. Davis, J. W. Davis, J. A. Deghuee, A. F. Delafield, Chas. J. Derleth, C. F. Dolan, H. E. Donnelly, J. S. Douglas, Charles Drasel, D. Le R. Dresser, I. W. Drummond, E. K. Dunham, B. H. Dutcher, W. G. Eberhardt, T. Egleston, A. H. El-

liott, W. Elliott, L. V. Emanuel, I. N. Evans, G. E. Fahys, P. Le R. Fearn, C. F. Ferrer, H. Feuchtwanger, W. Fisher, F. W. Floyd, R. G. Foster, A. E. Foyé, J. W. Frank, W. H. Freedman, S. D. Gifford, A. C. Gildersleeve, S. A. Goldschmidt, E. B. Gosling, L. P. Gratacap, A. D. Granger, J. L. Greenleaf, S. P. Griffin, L. N. Gross, E. Gudeman, E. W. Guiterman, L. F. Haffen, A. W. Hale, R. W. Hall, A. P. Hallock, A. W. Hankinson, R. C. Hanson, G. E. Harding, O. B. Hébert, A. M. Heinsheimer, H. H. Hendricks, W. E. Hildreth, F. N. Holbrook, E. C. Holden, E. H. Holden, W. A. Hooker, F. F. Hunt, F. R. Hutton, H. St. J. Hyde, O. Jackson, D. M. Jacobs, S. J. Jacobs, C. P. Carr, J. C. Kastner, J. F. Kemp, G. T. Kirby, H. S. Kissam, E. C. Koch, J. J. Koen, W. B. Kunhardt, J. Lahey, J. S. Langthorn, D. G. Leary, G. Leary, E. J. Lederle, A. R. Ledoux, A. L. Levy, E. W. Libaire, A. Liebmann, Henry Lipps, Jr., W. P. Little, A. R. Livingston, E. G. Love, Frank Ludlam, L. McI. Luquer, T. T. P. Luquer, G. Lusk, R. C. McCaffery, C. F. McKenna, R. A. McKim, J. Maclay, H. T. MacKaye, A. S. Mahony, L. F. Massa, R. E. Mayer, C. S. McLoughlin, H. C. Mannheim, L. Marie, E. W. Martin, L. F. Massa, F. C. A. Meisel, H. H. B. Meyer, E. H. Miller, R. P. Miller, J. T. Monell, M. R. Montenegro, D. E. Moran, W. F. Morgan, R. K. Mosley, A. J. Moses, Robert Mulford, George Müller, H. S. Munroe, C. E. Munsell, J. G. Murphy, K. Neftel, William Newbrough, D. H. Norris, E. L. Newhouse, A. C. Nye, M. J. O'Connor, T. D. O'Connor, Charles Of, E. E. Olcott, Max Osterberg, F. N. Owen, A. McC. Parker, H. C. Parker, C. F. Parraga, Henry Parsons W. B. Parsons, C. Q. Payne, Robert Peele, C. E. Pellew, C. P. Pengnet, Geo. Perrine, J. P. Pennington, W. Pistor, L. Pitkin, H. H. Porter, Jr., A. S. Post, A. V. Z. Post, F. Powell, W. E. Preston, J. C. F. Randolph, R. Raynor, S. A. Reed, J. K. Rees, G. Renault, J. M. Rich, P. de P. Ricketts, T. W. Ridsdale, H. Ries, Chas. Rodenburg, F. Roeser, O. L. Rogers, A. Rosenthal, P. Rupp, F. M. Rutherford, F. Ruttman, A. M. Ryon, E. E. Sage, F. A. Schermerhorn, W. J. Schiefflein, J. L. Schroeder, C. H. Schumann, C. D. Searle, J. G. Seligman, John Seward, F. D. Sherman, H. T. Shriver, F. M. Simonds, A. Smith, L. Smith, W. A. Smith, W. F. Smith, T. E. Snook, A. N. Spooner, J. H. Stewart, J. Struthers, G. A. Suter, J. B. Taylor, H. C. Thompson, W. H. Titus, E. DeV. Tompkins, G. F. Townsend, G. F. D. Trast, G. R. Tuska, E. G. Tuttle, A. H. Van Sinderin, E. Van Volkenburgh, H. T. Vulte, J. H. Wainwright, W. H. Weeks, H. McM. Welsh, J. S. C. Wells, William Y. Westervelt, R. D. White, T. G. White, H. P. Whitlock, F. G. Wiechmann. J. T. Williams, C. A. Wittmack, I. H. Woolson, E. L. Young; *Niagara Falls*, E. Z. Burns, W. S. Humbert; *Northport*, W. H. Ingersoll; *Ontario*, E. M. Parrot; *Oyster Bay*, D. Le R. Dresser;

Poughkeepsie, A. E. Tower; *Rochester*, H. P. Gillette, T. Nolan; *Rondout*, Edward Coykendall; *Schenectady*, M. L. Mora; *Sing Sing*, W. S. Page; *Smithstown*, J. H. B. Browning; *Spuyten Duyvil*, E. M. Johnson, G. H. Johnson, I. B. Johnson, L. B. Longacre; *Staten Island*, G. F. D. Trask; *Stirlengton*. Wm. Clark; *Syracuse*, H. B. Bellinger, W. N. Taintor; *Tarrytown*, F. N. Holbrook, L. B. Longacre; *Ticonderoga*, F. C. Hooper; *Tuxedo Park*, E. N. Van Cortlandt; *Utica*, G. W. Williams; *Westchester*, T. H. Harrington; *West Nyack*, S. O. Miller; *White Plains*, R. E. Slade; *Whitestone*, W. J. Wallace, D. W. Ward; *Whitestone Landing*, R. D. Godley, Jr.; *Yonkers*, S. W. Balch, W. D. Horne.

North Carolina.—*Charlotte*, S. W. Cramer, G. B. Hanna; *Wilmington*, F. S. Clark.

Ohio.—*Cincinnati*, David Foerster, C. B. Going; *Cleveland*, R. F. Jopling, R. B. Watson; *Marietta*, C. G. Slack; *Sandusky*, S. B. Newburg.

Pennsylvania.—*Allegheny*, G. H. Singer, L. Wertheimer; *Ambler*, E. Luttgen; *Apallo*, T. M. Hopke; *South Bethlehem*, A. L. Colby; *Chambersburg*, T. J. Brereton; *McKeesport*, T. Tonbelé; *New Boston*, J. E. Jones; *New Castle*, E. L. Kurtz; *Osceola Mills*, G. McC. H. Good; *Philadelphia*, E. A. Congdon, R. Lahey, S. M. Lillie, Charles Piez; *Pittsburg*, J. S. Cox, W. L. McConway, R. G. G. Moldehnke, G. S. Page, C. A. Painter, G. E. Painter, G. Singer, Jr.; *Scranton*, J. T. Beard; *Wilkesbarre*, Mac Dobbins, R. V. A. Norris; *Wyncote*, E. Luttgen.

Rhode Island.—*Providence*, Carl Barus.

Tennessee.—*Gallatin*, A. J. Lamb.

Texas.—*Eagle Pass*, W. Hollins; *Shafter*, W. S. Noyes.

Utah.—*Jensen*, A. G. Johnson; *Sandy*, L. H. Norton, *Salt Lake City*, T. S. Mathias, R. H. Terhune, W. A. Wilson.

West Virginia.—*Franklin*, T. W. Osterheld.

Wisconsin.—*Hurley*, G. H. Abeel.

Wyoming.—*Rawlins*, C. E. Blydenburgh.

Washington.—*Everett*, W. C. Butler; *Tacoma*, G. F. Milliken; *Spokane*, J. L. Warner.

OUT OF THE UNITED STATES.

AFRICA.

South Africa Republic.—*Johannesburg*, B. P. Carter, T. H. Leggett, H. C. Mannheim, E. D. Self, F. M. Watern, E. A. Wiltsie.

ASIA.

Japan.—*Tokio*, E. L. Young.

AUSTRALIA.

Kalgoorlie.—J. R. M. Raymond.
New South Wales.—Randolph Adams.
Port Pirie.—H. W. Leavens.

GREAT BRITAIN.

London.—C. M. Rolker.

NORTH AMERICA.

Canada.—*Nelson, B. C.*, S. S. Fowler; *Northport, B. C.*, E. H. Wedekind; *Montreal*, C. E. Gudewill, J. B. Porter; *Nova Scotia, Londonderry*, C. A. Meissner; *Quebec*, R. D. Rhodes.

SOUTH AMERICA.

Brazil.—*Rio de Janeiro*, John Gordon.
Republic of Columbia.—*Medellin*, C. C. Restrepo; *Tumaco*, W. B. McKinley, L. Whiting.

CENTRAL AMERICA.

Cuba.—*Clardenas*, D. L. Clark; *Cienfuegos*, A. C. Fowler.
Guatemala.—*Quezaltenang*, J. F. Hawley.
Honduras.—*Tegucigalpa*, E. C. Fiallos.
Mexico.—*Chihuahua*, T. S. Austin, G. B. Lee; *City of Mexico*, V. M. Braschi; *Coahuila*, E. L. Dufourcq, Gomez Farias; *Sinaloa*, A. E. Swain; *Tapachula Chiopas*, J. A. Navarro; *Concepcion del Oro*, A. W. Lilliendahl, F. A. Lilliendahl; *Hidalgo*, E. C. Van Blarcom; *Monterrey*, E. Howe; *Puebla*, T. W. Osterheld; *Zacatecas*, R. Yeizar.

CONSTITUTION

OF THE

ASSOCIATION OF THE ALUMNI

OF THE

SCHOOL OF MINES OF COLUMBIA COLLEGE.

INCORPORATED MAY, 1886.

ARTICLE I.

NAME.

THE name of this Association is "The Association of the Alumni of the School of Mines of Columbia College."

ARTICLE II.

OBJECT.

The object of this Association is to promote the professional welfare of its members, and to strengthen the bonds of professional and social fellowship among the Alumni of the School of Mines.

ARTICLE III.

MEMBERS.

SECTION 1. The membership of this Association shall be: I. Active. II. Associate. III. Honorary.

SEC. 2. All graduates of the School of Mines are eligible to active membership in this Association.

SEC. 3. Persons who have completed any of the special or graduate courses of the School of Mines are eligible to associate membership in this Association.

SEC. 4. Persons eminent in science who are or have been connected with the School of Mines are eligible to honorary membership in this Association.

SEC. 5. All members shall be elected by the Association upon proposal by the Board of Managers.

SEC. 6. Honorary and associate members shall have all the privileges of active members, except those of voting and holding office.

ARTICLE IV.

DUES.

SEC. 1. The annual dues of active and associate members of this Association shall be three dollars, payable in advance on the first day of October in each year. Honorary members shall not be required to pay dues.

SEC. 2. Any member not in arrears may become a life member, and be relieved from further payment of annual dues by the payment, at any one time, of fifty dollars.

SEC. 3. Members one year in arrears may, after due notification, be dropped from the roll, by vote of the Board of Managers, and shall then forfeit their rights and privileges in the Association until all arrears are paid, or until reinstated by the Board.

SEC. 4. Only those members not in arrears shall be entitled to vote or hold office.

ARTICLE V.

OFFICERS AND MANAGERS.

SEC. 1. The officers of the Association shall be a President, a Vice-President, a Treasurer, and a Secretary. These officers and eight managers, to be elected as hereinafter provided, shall constitute the Board of Managers.

SEC. 2. The President, Vice-President, Treasurer and Secretary shall hold office for one year, and are eligible for re-election. The Managers shall hold office for two years, and are not eligible for re-election until one year after the expiration of their terms.

ARTICLE VI.

ELECTION OF OFFICERS AND MANAGERS.

SEC. 1. Before the last day of June of each year the President shall appoint a committee of five active members to nominate for election by the Association for the ensuing year a President, a Vice-President, a Treasurer, a Secretary and four Managers.

SEC. 2. The Nominating Committee must send in the nominations to the Secretary not later than October 15th of each year, and such nominations shall be distributed at once to the active members in the form of letter ballots, which must be signed and forwarded to the Secretary, and opened and counted by tellers at the annual meeting of the Association.

SEC. 3. The officers and managers must be residents of New York city or vicinity, and the four managers shall he selected, one from each of the four groups into which the Board of Managers shall, at its first meeting in each year, divide in chronological order the classes which have graduated from the School of Mines.

ARTICLE VII.

THE BOARD OF MANAGERS.

SEC. 1. The Board of Managers shall have the management of the affairs, funds and property of the Association, and it shall be the duty of the Board to see that the purposes of the Association are carried out according to its Constitution and By-Laws.

SEC. 2. The Board of Managers shall hold at least four regular meetings during each year, namely, in the months of January, May, October and December. Other meetings shall be called by the President as may be required.

SEC. 3. The Board shall have power to fill any vacancy in its body by the election of an active member of the Association from the group in which such vacancy occurs.

SEC. 4. A quorum shall consist of a majority of the whole Board.

ARTICLE VIII.

PRESIDENT.

It shall be the duty of the President to call and preside at all meetings of the Board of Managers and of the Association; to appoint such standing and other committees of the Association as may be found necessary or convenient for the conduct of its work, and to perform such other duties as may develop upon him by virtue of his office.

ARTICLE IX.

TREASURER.

It shall be the duty of the Treasurer to collect and have custody of all moneys and pay all bills of the Association, but no indebtedness shall be incurred unless approved by the Board of Managers. No bill shall be paid unless previously endorsed by the Secretary. The Treasurer shall present to the Board of Managers a written report upon the financial condition of the Association at the annual meeting in December. His accounts shall be audited by a committee of the Association appointed at the annual meeting.

ARTICLE X.

SECRETARY.

It shall be the duty of the Secretary to issue notices for all meetings of the Board of Managers and of the Association, to keep minutes of all meetings, to record the names, addresses, and professional occupations of the members, and to perform such other duties as may be assigned to him by the Board of Managers.

ARTICLE XI.

DELEGATES TO UNIVERSITY ALUMNI COUNCIL.

This Association shall be represented in the University Alumni Council of Columbia University by delegates appointed by the Board of Managers, under such conditions and in such manner as the said Board shall prescribe.

ARTICLE XII.

MEETINGS.

SECTION 1. The annual meeting of the Association shall be held in the last week of December in each year, unless otherwise ordered by the Board of Managers.

SEC. 2. Regular meetings of the Association for social intercourse, or for the discussion of subjects of general or of professional interest, shall be held in the city of New York at such time and place as may be directed by the Board of Managers.

SEC. 3. Upon the written request of not less than ten active members, the President shall call a special meeting of the Association, which request, as also the notice of any special meeting, shall state the object for which the meeting is called.

SEC. 4. A quorum shall consist of thirty active members of the Association.

ARTICLE XIII.

SUSPENSION OR EXPULSION.

Any member of the Association may be suspended or expelled for misconduct in his relations to this Association or in his profession on proof thereof in such manner as may be prescribed hereinafter by By-laws.

ARTICLE XIV.

All interest in the property of the Association of persons resigning or otherwise ceasing to be members shall vest in the Association.

ARTICLE XV.

AMENDMENTS.

Any amendment to the Constitution must first be submitted in writing to the Board of Managers, and must be approved by a vote of two-thirds of the whole Board before presentation to the Association. Due notice of any proposed amendment shall be sent by the Board of Managers to every active member of the Association at least one month previous to the meeting at which such amendment is to be voted upon. A three-fourths' vote of the members voting, in person or by letter ballot, shall be necessary for the adoption of such proposed amendment.

BY-LAWS.

I. Unless otherwise directed the Order of Business at any meeting of the Association and its Board of Managers shall be as follows:

1. Reading of minutes of preceding meetings and action thereupon.
2. Report of the Board of Managers.
3. Reports of officers.
4. Reports of standing committees.
5. Reports of special committees.
6. Elections and announcement of elections.
7. Unfinished business.
8. New business.
9. Appointment of committees.
10. Adjournment.

II. The absence of any member of the Board of Managers from two consecutive meetings of the same, of which he shall have been regularly notified, shall be considered as a resignation on the part of such member, unless the Board shall excuse such absence. The vacancy thus created shall be filled as provided for in the Constitution.

III. The Standing Committees of the Board of Managers shall be as follows:

1. On School of Mines Quarterly.
2. On Badges.
3. On Meetings of the Association.

4. Of Conference with the Columbia College Alumni Association, and such other Committees as may be necessary.

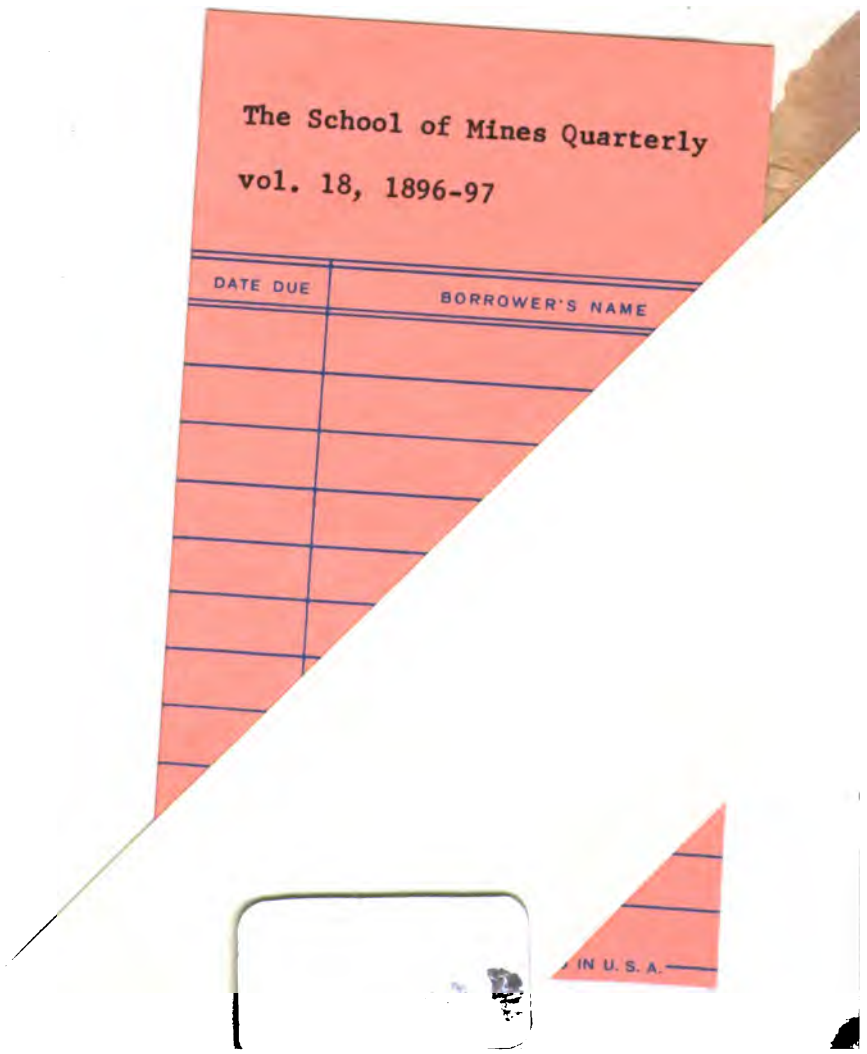
All such committees shall be at the expiration of their terms of office, present written reports to the Board of Managers.

IV. The official organ of this organization shall be the SCHOOL OF MINES QUARTERLY, which will be furnished to all active and associate members.

V. The Standing Committee on Meetings shall arrange for regular meetings of the Association in October and March of each year unless otherwise ordered by the Board of Managers.

VI. These By-Laws may be amended at any regular meeting of the Association, but only by a vote of two-thirds of those present, and provided that ten days' notice in writing of the proposed amendment shall have been given to the Board of Managers, and also that notice of the same shall have been given by the Secretary in the call for the meeting.

SERIAL


The School of Mines Quarterly
vol. 18, 1896-97
DATE DUE
BORROWER'S NAME
IN U. S. A.